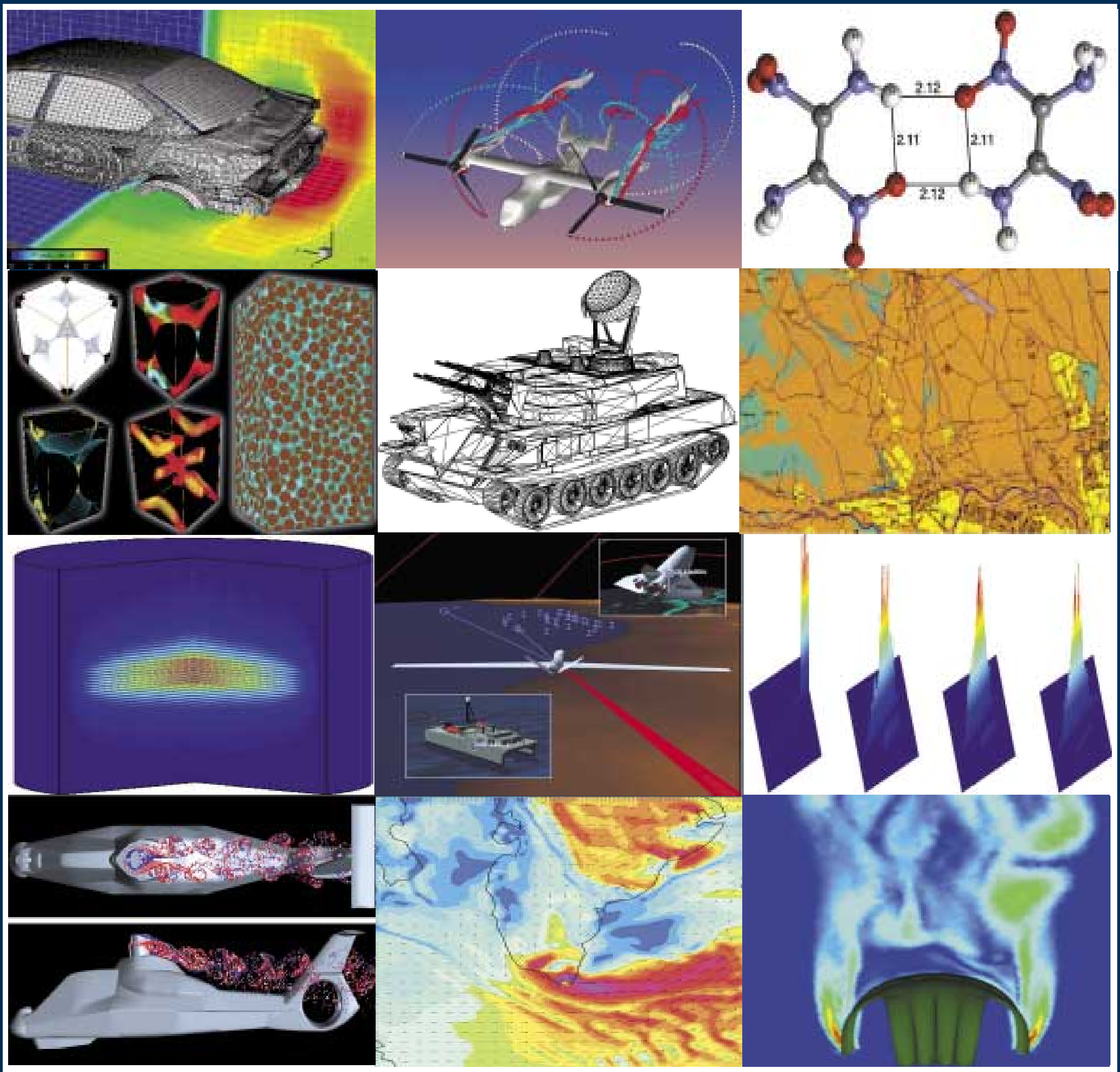

High Performance Computing

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DoD Mission Success 2000

First row (left to right):

Response of an automobile to a large blast from the rear. This simulation has over 100,000 elements. (p.89)

The V-22 rotor-wake system is visualized in a post process where filaments of particles are released from inboard and outboard blade-tips every 25 time-steps. (p.36)

RHF/6-311G(d,p) optimized geometry of 1,2-diamino-1,2-dinitroethylene dimer. (p.60)

Second row (left to right):

Simulated porous media showing close up of flow field components. (p. 49)

ZSU facet model shown at 12° depression angle and 45° azimuth angle. (p.82)

Detailed view using VPF level 2 data. (Figure 2, p.73)

Third row (left to right):

The lasing-mode optical-field intensity pattern, inside the laser, for a micro-cavity laser with an oxide aperture placed at the optical-intensity standing-wave null. Notice that the oxide-aperture does not provide much (radial) confinement of the optical field due to the fact it is located at the standing-wave null. (Figure 1, p. 71)

System Virtual Prototyping, a screen capture from the ADVISR real-time, three-dimensional visualization system. (p. 42)

Sonar receiver response for successive transmissions using an autofocus technique on a towed line array. The algorithm adapted for platform dynamics and acoustic propagation providing improved sonar track estimation over conventional navigation instrumentation. (p.76)

Fouth row (left to right):

Unsteady flow over an isolated Comanche helicopter fuselage (top and side views). Particles released from the base of the rotor hub reveal vortex shedding and downstream convection to the vehicle tail section.

Near surface wind speed (knots) for ~1200 UTC 18 February 1997 derived from a COAMPS 24-h simulation fields. (p. 78)

Computational analysis of a cross-parachute. The figure shows the side view together with the computed vorticity.

For more information about the DoD HPC Modernization Office and the DoD HPC Modernization Program, visit our Web site at http://www.hpcmo.hpc.mil

High Performance Computing

contributions to

DoD Mission Success 2000

December 2000

OFFICE OF THE DIRECTOR OF
DEFENSE RESEARCH AND ENGINEERING
3040 DEFENSE PENTAGON
WASHINGTON, DC 20301-3040

The Department of Defense (DoD) High Performance Computing Modernization Program (HPCMP) provides world-class, commercial, high-end high performance computing capability to the DoD science and technology and test and evaluation communities. The program supports over 600 high performance computing projects. The user base exceeds 5,000 scientists and engineers, who are located at more than 100 DoD laboratories, test centers, contractor, and academic sites. The program's real successes, however, are the Department's scientific and engineering achievements and their contribution to unprecedented United States technological warfighting advantage. The 49 representative stories presented in the 2000 edition of *High Performance Computing Contributions to DoD Mission Success* highlight the scope and diversity of computational science being accomplished using HPCMP resources.

These success stories, which respond to defense needs documented in the Department's *Defense Technology Area Plan,* span the ten computational technology areas of the Department's scientific community. The stories are a tribute to the outstanding accomplishments of DoD scientists and engineers and their ability to put advanced technology in the hands of U.S. forces more quickly, less expensively, and with a greater certainty of success. Some projects focus on generic defense science challenges, however, this year's collection shows the growing importance of high performance computing in the modeling and simulation of the next generation of warfighting systems. Included in this edition are projects relating to the Joint Strike Fighter (pp. 25 & 50), Buried Land Mines (p. 92), Novel Lethal Mechanisms for Missile Applications (p. 104) Contaminant Transport Modeling (p. 112), and Army Ground and Tracked Vehicles (p. 116). High performance computing is critical for these and similar major programs. New materials, better fuels, enhanced stealth characteristics, reduced vulnerability, improved external stores, and comprehensive evaluation of structural design of entire platforms – all are represented in this technical report, and all require high performance computing.

These stories are indicative of future requirements fundamental to defense superiority in the 21st century. The United States defense community, using HPCMP resources, will maintain superiority across the spectrum of conflict, and the U.S. warfighter will be assured an unparalleled technological edge on the battlefield.

Delores M. Etter

Delores M. Etter
Deputy Under Secretary of Defense
(Science and Technology)

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Section 1
Introduction

"Obsolete weapons do not deter." — Margaret Thatcher

FOREWORD

This technical report is the forth in a series of reports originally issued in 1995 that describes some of the scientific research and engineering successes the Department of Defense (DoD) is realizing through its investment in the High Performance Computing Modernization Program (HPCMP). Initiated in 1992 under the oversight of the Director, Defense Research and Engineering, the HPCMP has developed into a vital, powerful resource supporting the science, technology, and test activities of the Department. The HPCMP provides high end, commercially available high performance computing hardware, software, networking, and support services to over 5,000 scientists and engineers working in the Department, academia, and commercial firms at more than 100 locations in 28 states. The advances made using high performance computing resources allows the United States to maintain its technological superiority over present and future adversaries, shortening the development cycle, and providing engineering solutions in a fraction of the time spent using conventional resources. The HPCMP user-community is organized around ten computational technology areas (CTAs), providing a logical concentration of expertise and leadership to guide the technical development.

This report is organized into three sections. Section 1, Introduction, discusses the history of the program, its current structure and initiatives and summarizes its impact on the DoD. Section 2, Success Stories, provides abstracts of a sampling of the successes the Department is realizing using high performance computing assets. For ease of reference, section two is organized to conform to the general categorizations found in the Defense Technology Area Plan (DTAP), one of the basic planning documents of the Department's scientific community. Section 3, References, contains references applicable to the stories detailed in Section 2.

The High Performance Computing Modernization Program receives guidance and direction from the Deputy Under Secretary of Defense (Science and Technology) [DUSD(S&T)] for the application of its resources to the Department's science, technology, test, and evaluation objectives. That direction is developed through an annual planning and allocation process that actively involves the Services and Agencies as well as prominent scientists in the national community. This process helps to ensure the program fully supports the vision and objectives described in the Joint Chiefs of Staff's Joint Vision 2020 and the Defense Science and Technology Strategy. As stated in the DTAP,

> " The foundation of this process is the *Defense Science and Technology Strategy* with its supporting *Basic Research Plan (BRP)*, *Joint Warfighting Science and Technology Plan (JWSTP)*, and *Defense Technology Area Plan (DTAP)*. …The DTAP documents the focus, content, and principal objectives of the overall DoD science and technology efforts. This plan provides a sound basis for acquisition decisions and is structured to respond to the DUSD(S&T)'s emphasis on rapid transition of technology to the operational forces."

DTAP technology areas include Air Platforms; Chemical/ Biological Defense and Nuclear; Information Systems Technology; Ground and Sea Vehicles; Materials/Processes; Biomedical; Sensors, Electronics, and Battlefield Environment; Space Platforms; Human Systems; Weapons; and Nuclear Technology.

DoD High Performance Computing Modernization Program (HPCMP)

History

The High Performance Computing Modernization Program (HPCMP) was initiated in 1993 in response to congressional direction to modernize the Department of Defense (DoD) laboratories' high performance computing (HPC) capabilities. Today, the HPCMP fields world-class, commercial high performance computing capabilities, available to the full Science and Technology (S&T) and Test and Evaluation (T&E) communities, that includes a balanced set of major shared resource centers, smaller focused distributed centers, wide area networking services, and HPC software development support.

These capabilities allow our scientists and engineers to incorporate technological advantage into superior weapons, warfighting capabilities, and related support systems more rapidly and affordably with reduced risks to human life and optimized system performance.

Scope

The HPCMP scope is bounded both in terms of the user communities it serves and the technological capability that it delivers. By limiting the scope and by concentrating the majority of resources at a small number of HPC centers, the program has been able to provide world-class computing capabilities that could not have efficiently been obtained and sustained by individual Services or Agencies. This sharing of resources reduces overall acquisition and sustainment costs, helps to reduce acquisition leadtime, and fosters collaboration and cooperation across the DoD S&T and T&E communities.

The scope of the user communities are defined by the Congress (Public Law 104-61, December 1, 1995, 109 Statute 665, Sec. 8073) to be

> *"(1) the DoD Science and Technology sites under the cognizance of the DDR&E, (2) the DoD Test and Evaluation centers under the Director, Test and Evaluation OUSD (A&T), and (3) the Ballistic Missile Defense Organization."*

Impact to DoD

As shown in Table 1, several of the DTAP focus areas benefit greatly from the use of high performance computing resources. For example, in the Air Platform technology area, high performance computing supports research and engineering analysis in the areas of flight control and integration. In another Air Platform area, rotary-wing research is being conducted to assess the operational issues of survivability, ground effects characterization and control, and rotorcraft improvement studies. In the Sensors, Electronics, and Battlespace Environment technology area, simulations are being used to optimize micro-cavity lasers, to model the design of arrays, and to improve surveillance systems. This work will eventually reduce the exposure and detectability of U.S. and friendly forces. In the Weapons technology area, high performance computing resources are being used to create "real-world" scenes that will give testers, warfighters, and planners additional tools to make value judgements about the development, improvement, and acquisition of infrared systems. Simulations are being used to model the interaction of elastic waves with buried land mines, prototyping high power microwave weapon designs, and improving missile control jet design.

Table 1. Success Stories Supporting the Defense Technology Area Plan (DTAP) by CTA

Computational Technology Areas/Stories	Defense Technology Area Plan: Air Platforms	Information Systems Technology	Materials/ Processes	Sensors, Electronics, and Battlespace Environment	Weapons	Other*
Computational Structural Mechanics (CSM)						
Virtual Wind Tunnel for Virtual Prototyping and Design	●	●				
Ordnance Detonation and Penetration Mechanics Modeling		●			●	
Novel Lethal Mechanisms for Missile Applications		●			●	
Scalable, Strongly-Coupled, Large Deformation Simulations of Fluid Structure Interactions		●			●	●
Simulation Based Acquisition (SBA) of the USMC Medium Tactical Vehicle Replacement (MTVR)			●			●
CFD-Based Rotorcraft Improvement Studies	●					
Meshfree Methods for Prediction of Structural Damage		●	●		●	
TARDEC Expands Real-Time Modeling of Ground and Tracked Vehicles		●				●
Response Predictions for Structure Collaps Experiments		●			●	
Damage Simulations in Hard and Deeply Buried Targets Due to Internal Blast and Shock Loading		●			●	
Ballistic Shock Propagation		●				●
Computational Fluid Dynamics (CFD)						
Simulation of the V-22 Tiltrotor Aircraft in High-Speed Cruise	●	●				
Attenuation of Shocks Through Structured Media		●	●			
Limit-Cycle Oscillations of a Cropped Delta Wing	●	●				
Synthetic Jet Actuators--A Novel Approach to Flow Control	●					

* Other includes Biological/Chemical Defense and Nuclear, Ground and Sea Vehicles, and Space Platforms.

Table 1. Success Stories Supporting the Defense Technology Area Plan (DTAP) by CTA—Continued

	Defense Technology Area Plan					
Computational Technology Areas/Stories	**Air Platforms**	**Information Systems Technology**	**Materials/ Processes**	**Sensors, Electronics, and Battlespace Environments**	**Weapons**	**Other***
Computational Fluid Dynamics (CFD) continued						
Solution on an F/A-18C with Stores in Carriage	●	●			●	
Rotating Marine Propulsor Simulation		●				●
Numerical Simulation of a Controlled Store Release from an F-15	●	●			●	
Self-Propelled Submarine Maneuver Induced by a 10 Degree Rudder Deflection		●				●
Improving Missile Control Jet Design	●	●			●	
Reynolds Number Scaling	●					
Contaminant Transport Modeling in Complex Urban Environments		●				●
Micro Air Vehicle Design	●	●		●		
Simulation of Turbulent Combustion in a Full-Scale Combustor	●	●	●			●
CFD Analysis of Surge and Rotating Stall Control in Compressors	●					
Weapons of Mass Destruction Defeat Payload Development		●				●
Assessing the Terrorist Attack on the U.S. Embassy in Nairobi, Kenya		●			●	
ZNSFLOW CFD CHSSI Software		●			●	
ComputationalChemistry and Materials Science (CCM)						
The Tight-Binding Method as a Predictor of Novel Materials and Properties			●			
Computational Chemistry Models of Gun Tube Erosion		●	●			

* **Other includes Biological/Chemical Defense and Nuclear, Ground and Sea Vehicles, and Space Platforms.**

Table 1. Success Stories Supporting the Defense Technology Area Plan (DTAP) by CTA—Continued

	Defense Technology Area Plan					
Computational Technology Areas/Stories	Air Platforms	Information Systems Technology	Materials/ Processes	Sensors, Electronics, and Battlespace Environments	Weapons	Other*
Computational Chemistry and Materials Science (CCM) continued						
Design of High Energy Density Materials			●			●
Thermal Degradation of Ceramic Interfaces			●			●
Computational Electromagnetics and Acoustics (CEA)						
Wide-Frequency-Band Antenna Simulation Capability	●	●		●		
Accurate Schemes for Wave Propagation and Scattering				●		
Flow Control through Non-Ideal Magnetogasdynamic Simulation	●	●				●
Virtual Prototyping Confirms Benefits of a Proposed High Power Microwave Source Design Modification		●		●	●	
A Numerical Model for the Interaction of Elastic Waves With Buried Land Mines		●			●	
RCS and ISAR Image Predictions for Combat Ground Vehicles				●		●
Radar Signature Predictions with the Highly Scalable, Higher Order SWITCH Code	●			●		
Climate/Weather/Ocean Modeling and Simulation (CWO)						
Flow Response to Large-Scale Topography: The Greenland Tip Jet		●		●		●
A Feasibility Demonstration of Ocean Model Eddy-Resolving Nowcast/Forecast Skill Using Satellite Altimetry		●		●		
First 1/32DEG Global Ocean Model		●		●		●
Operational Wave Forecasting in Scalable Environments		●		●		●

* Other includes Biological/Chemical Defense and Nuclear, Ground and Sea Vehicles, and Space Platforms.

Table 1. Success Stories Supporting the Defense Technology Area Plan (DTAP) by CTA—Continued

	Defense Technology Area Plan					
Computational Technology Areas/Stories	Air Platforms	Information Systems Technology	Materials/ Processes	Sensors, Electronics, and Battlespace Environments	Weapons	Other*
Signal/Image Processing (SIP)						
Data Distribution Environment for Signal Processing Applications on Parallel Architectures		●		●		
Synthetic Aperture Radar Image Formation (SARIF)		●		●		
Real-Time Processing of Hyperspectral Sensor Data		●		●		●
Embedded Applications for Signal/Image Processing		●		●		
High Performance Computing for C3I CEM Applications		●		●		
Forces Modeling and Simulation/C4I (FMS)						
World Wide to Regional Mapping Engine		●		●		
V-22 Operational Evaluation	●	●		●		
Joint Strike Fighter--Virtual Strike Warfare Environment	●	●		●		
Environmental Quality Modeling and Simulation (EQM)						
Three-Dimensional Groundwater Modeling for Determination of Environmental Impacts Associated with Deep Underground Mining		●	●			●
Dynamically-Coupled Surface Water and Groundwater Modeling in Everglades National Park and South Florida		●	●			●
Coupled Structured-Unstructured Flow Simulation		●	●			●
Solving Groundwater Remediation Problems		●	●			
Verification of Theory for Dispersion of Groundwater Contaminants		●	●			●
Modeling the Chemical Interactions of Nitroaromatic Compounds with Soil		●	●			●
Long-Term Simulations of Aquatic Systems		●	●			●

* Other includes Biological/Chemical Defense and Nuclear, Ground and Sea Vehicles, and Space Platforms.

Table 1. Success Stories Supporting the Defense Technology Area Plan (DTAP) by CTA—Continued

	Defense Technology Area Plan					
Computational Technology Areas/Stories	**Air Platforms**	**Information Systems Technology**	**Materials/ Processes**	**Sensors, Electronics, and Battlespace Environments**	**Weapons**	**Other***
Computational Electronics and Nanoelectronics (CEN)						
Scalable Sensor Modeling		●		●		
Parallel Electromagnetic Solvers for High-Frequency Antenna and Circuit Design		●		●		
Large-Scale Simulations of Tiny Ultra-Low Threshold Micro-Cavity Lasers		●		●	●	
Integrated Modeling and Test Environments (IMT)						
Advanced Virtual Intelligence, Surveillance, and Reconnaissance (ADVISR)		●				
Resin Impregnation Process Simulations for Joint Strike Fighter (JSF) Aerospace	●	●	●			
Real-Time Scene Generation Techniques		●				●

* Other includes Biological/Chemical Defense and Nuclear, Ground and Sea Vehicles, and Space Platforms.

HPCMP Program Initiatives

The program is managed through three key initiatives. The initiatives are HPC centers, Networking, and the Common High Performance Computing Software Support Initiative (CHSSI). The initiatives improve the ability of users to analyze, develop, and deploy advanced weapons, warfighting capabilities, and related support systems more rapidly and affordably with reduced risk to human life and with optimal system performance.

HPC Centers

Major Shared Resource Centers and Distributed Centers

The HPCMP operates four large Major Shared Resource Centers (MSRCs) to enable the DoD S&T and T&E communities to effectively and efficiently use the full range of high-end HPC resources. Each MSRC includes a robust complement of high-end high performance computing and communications systems, scientific visualization capabilities, peripheral and archival mass storage devices, and support staff providing expertise in the use of these assets. The MSRC emphasis is on supporting large computational projects. Each MSRC is operated and maintained by a team of government and contractor personnel. The four MSRCs are:

- Aeronautical Systems Center (ASC), Wright-Patterson AFB, OH
- Army Research Laboratory (ARL), Aberdeen Proving Ground, MD
- Army Engineer Research and Development Center (ERDC), Vicksburg, MS
- Naval Oceanographic Office (NAVO), John C. Stennis Space Center, MS

In addition to the four MSRCs, the HPCMP operates 17 Distributed Centers (DCs) to provide HPC capability to a specified local and remote portion of the HPC user community. Modest-sized systems are deployed to DCs where there is a significant advantage to having a local HPC system and where there is a unique potential for advancing DoD applications. DCs leverage HPC expertise or address problems that cannot be readily solved at the MSRCs, such as real-time or near-real-time processing, embedded system applications, and man-in-the-loop and hardware-in-the-loop testing and evaluation. The centers are linked by a high-speed communications network to the MSRCs and remote users. Thus, they augment the MSRCs to form the total DoD HPCMP computational capability. The 17 DCs are:

- Air Armament Center (AAC), Eglin AFB, FL [Air Force]
- Air Force Flight Test Center (AFFTC), Edwards AFB, CA
- Air Force Research Laboratory, Information Directorate (AFRL/IF), Rome, NY
- Air Force Research Laboratory, Sensors Directorate (AFRL/SN), Wright-Patterson AFB, OH
- Arctic Region Supercomputing Center (ARSC), Fairbanks, AK [Air Force]
- Army High Performance Computing Research Center (AHPCRC), Minneapolis, MN
- Arnold Engineering Development Center (AEDC), Arnold AFB, TN [Army]
- Joint National Test Facility (JNTF), Schriever AFB, CO [Ballistic Missile Defense Organization]
- Maui High Performance Computing Center (MHPCC), Kihei, HI [Air Force]
- Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River, MD
- Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, CA

- Naval Research Laboratory (NRL-DC), Washington, DC
- Redstone Technical Test Center (RTTC), Huntsville, AL [Army]
- Space and Missile Defense Command (SMDC), Huntsville, AL [Army]
- Space and Naval Warfare Systems Center (SSC-SD), San Diego, CA [Navy)]
- Tank Automotive Research, Development and Engineering Center (TARDEC), Warren, MI [Army]
- White Sands Missile Range (WSMR), White Sands Missile Range, NM [Army]

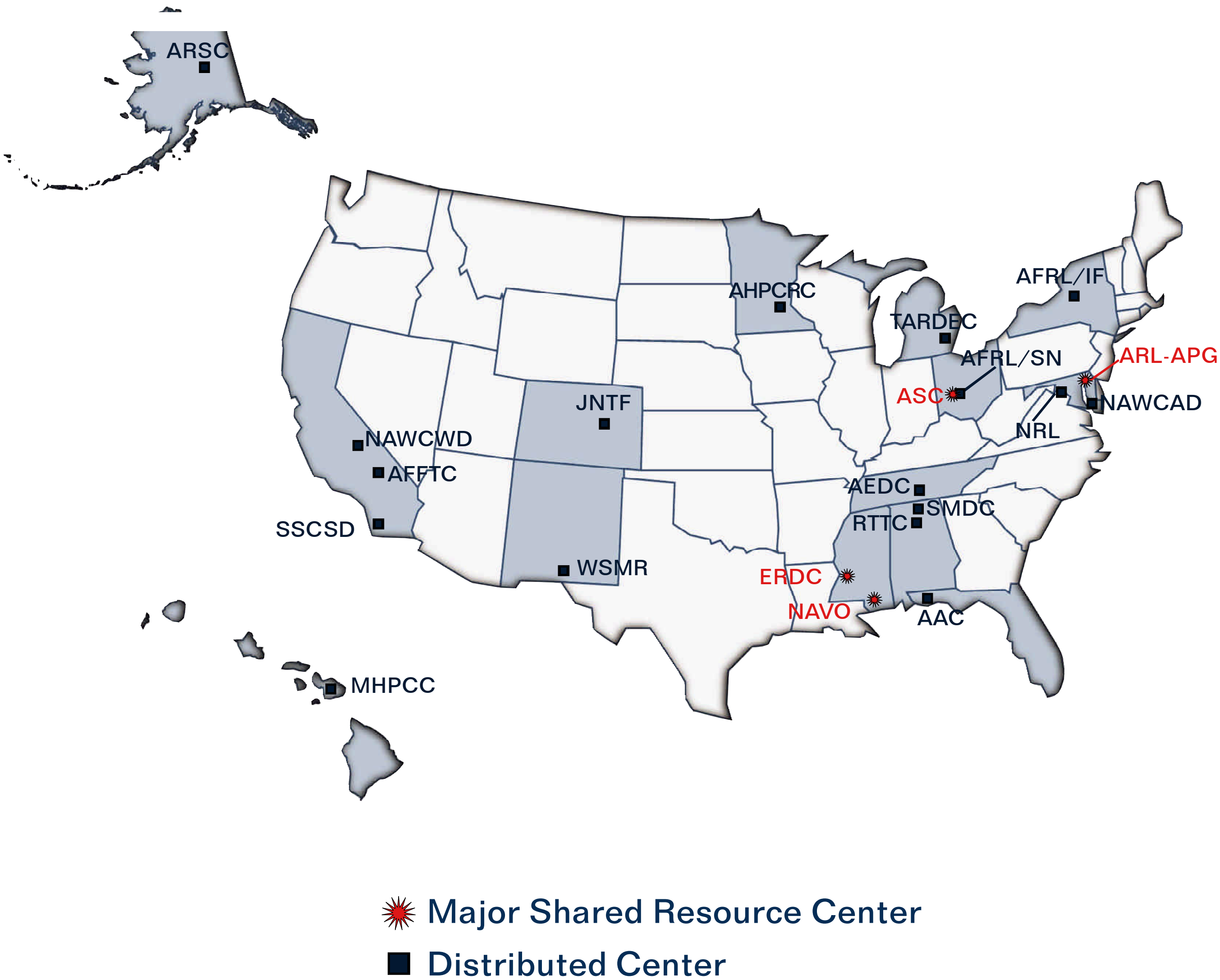


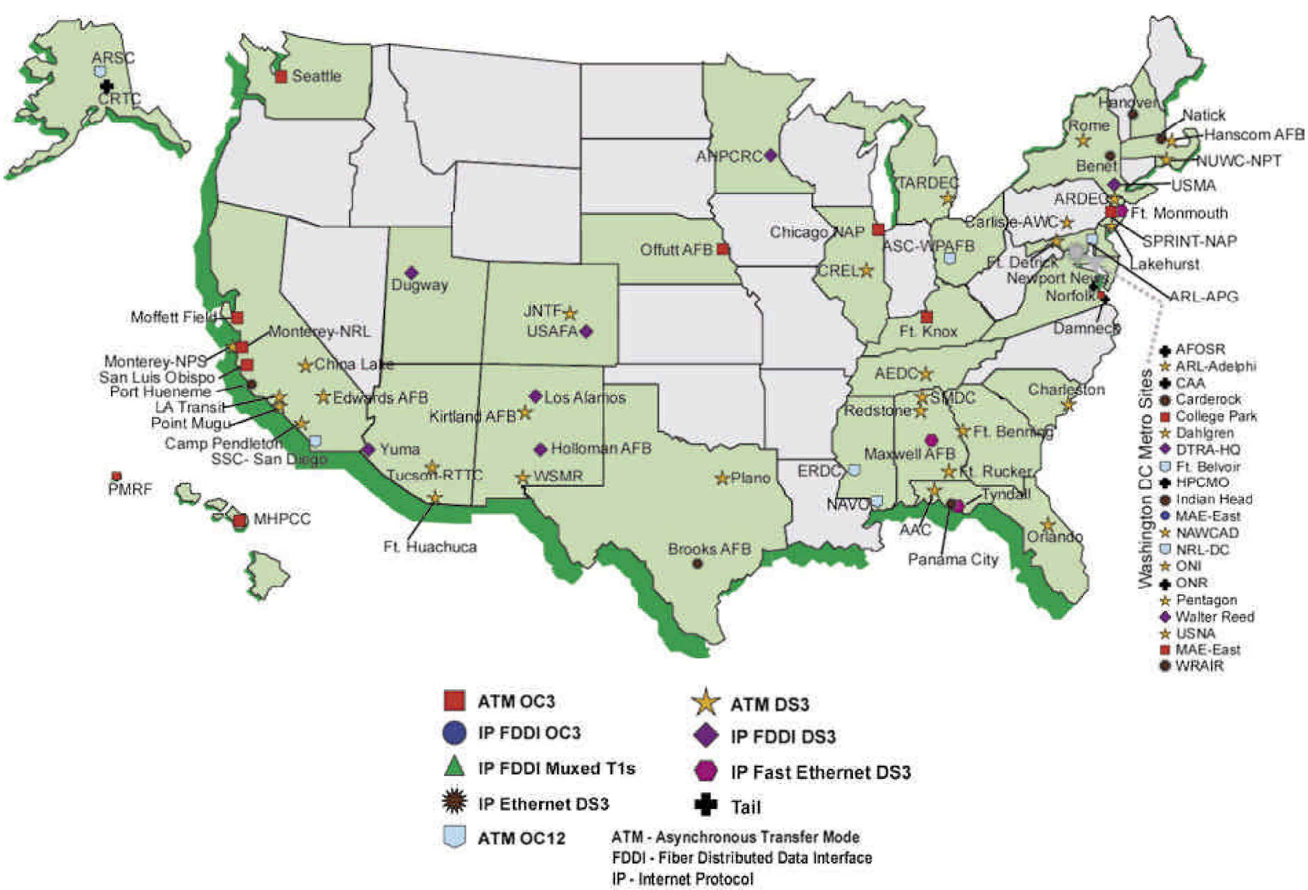
Figure 1. HPC Centers

Networking

The Defense Research and Engineering Network (DREN) is a Assistant Secretary of Defense Command, Control, Communications, and Intelligence approved Defense Department data communications network. The DREN provides the users with wide area network services through a virtual private network using a public Asynchronous Transfer Mode (ATM) communications infrastructure supplied by American Telephone & Telegraph (AT&T). DREN provides HPC users with transparent access to and from other commercial Internet service providers while maintaining traditional federal peering relationships with other government agencies. Peering allows networks to exchange routing information directly, thereby enabling the most efficient path for transmitting data. DREN has also established important peering initiatives with current federal network initiatives, such as the Next Generation Internet (NGI), the Internet2 ABILENE project, and the National Science Foundation's very high performance Backbone Network Service (vBNS).

DREN provides interoperable ATM and Internet Protocol (IP) services for digital video, audio, imaging, and data. Currently, network access capabilities range from DS3 (45 million bits per second) to OC-12c (622 million bits per second) with OC-48c (2.4 billion bits per second) available by 2001. DREN fully supports evolving protocols such as multicasting. State-of-the-art National Security Agency (NSA) approved security technology encrypts and protects HPC classified data transmissions across the Wide Area Network (WAN). As HPCMP networking requirements continue to evolve, DREN will continue to provide the best commercially available support for applications such as distributed computing, remote training, distance learning, virtual workshops, and remote interactive visualization.

Figure 2. Defense Research and Engineering Network (DREN) Sites



Common High Performance Computing Software Support Initiative

The Common High Performance Computing Software Support Initiative (CHSSI) ensures that efficient, scalable, portable software codes, algorithms, tools, models, and simulations that run on a variety of HPC platforms and are provided to a large number of S&T and T&E scientists and engineers. CHSSI is organized around the ten CTAs and involves scientists and engineers working in close collaboration across government, industry, and academia. CHSSI teams include algorithm developers, applications specialists, computational scientists, computer scientists and engineers, and end users.

Developing software for scalable HPC systems remains a technically challenging and labor intensive effort. CHSSI is helping the DoD take advantage of existing and future computing and communications capabilities by building software with an emphasis on reusability, scalability, portability and maintainability. In addition, CHSSI is producing a new generation of world-class scientists and engineers trained in scalable software techniques that will reduce the future costs of doing business and increase our future defense capabilities. Table 2 lists the current CHSSI code development efforts and the principal investigators. Nineteen of these efforts are CTA-specific projects. Four multi-disciplinary portfolios are also under development. These portfolios encompass the 18 projects designed to span across multiple CTAs.

Table 2. Common HPC Software Support Initiative Projects and Principal Investigators

Project	Principal Investigator	Organization
Computational Structural Mechanics		
A Next Generation Scalable Finite Element Software to Describe Fracture and Fragmentation of Solids and Structures	Dr. A.M. Rajendran	Army Research Laboratory, Aberdeen Proving Ground, MD
Computational Fluid Dynamics		
SUPREM DSMC: Scalable, Parallel, Reacting, Multidimensional Direct Simulation Monte Carlo Flow Code	Dr. Ingrid Wysong	Air Force Research Laboratory, Propulsion Directorate, Edwards AFB, CA
Computational Chemistry and Materials Science		
Fast Parallel Total Energy Methods for Multiple Length Scales	Dr. Dimitrios Papaconstantopoulos	Naval Research Laboratory, Washington, DC
Molecular Dynamics for Energetic and Non-Energetic Materials	Dr. Dimitrios Papaconstantopoulos	Naval Research Laboratory, Washington, DC
Computational Electromagnetics and Acoustics		
A Scalable, Dynamically Adaptive Mesh Software Package for General Magnetohydrodynamic and Space Weather Modeling	Dr. Sprio Antiochos	Naval Research Laboratory, Washington, DC
MACH3: Portable, Scalable, Parallel-Computing Magnetohydrodynamics Software for Multi-materials in Complex 3-D Geometry	Dr. Robert Peterkin	Air Force Research Laboratory, Directed Energy Directorate, Kirtland AFB, NM
Software Development for Electromagnetic Sensing of Surface and Subsurface Targets: Simulation and Signal Processing	Dr. Anders Sullivan	Army Research Laboratory, Adelphi, MD

Table 2. Common HPC Software Support Initiative Projects and Principal Investigators—Continued

Project	Principal Investigator	Organization
Climate, Weather, and Ocean Modeling and Simulation		
Development of Two Complete Numerical Weather Prediction Systems for Heterogeneous Scalable Computing Environments	Dr. Thomas Rosmond	Naval Research Laboratory, Monterey, CA
Satellite Radiance Variational Data Assimilation: Code Migration to Scalable Architectures	Dr. Frank Ruggiero	Air Force Research Laboratory, Space Vehicles Directorate, Hanscom AFB, MA
Scalable Ocean Models with Data Assimilation	Dr. Alan Wallcraft	Naval Research Laboratory, Stennis Space Center, MS
Scalable Weather Research and Forecast (WRF) Model Development	Dr. Jerry Weigiel	Air Force Weather Agency, Offutt AFB, NE
Signal/Image Processing		
Efficient, Maintainable, Portable, and Scalable HPC Codes for Image Fusion and Signal/Image Processing	Dr. Richard Linderman	Air Force Research Laboratory, Information Directorate, Rome, NY
Infrared Search and Track Processing for Missile Surveillance	Mr. Dennis Cottel	Space and Naval Warfare Systems Center, San Diego, CA
Acoustic Analysis Workbench Using Windows NT	Dr. Keith Bromley	Space and Naval Warfare Systems Center, San Diego, CA
Forces Modeling and Simulation/C4I		
Simulation and Analysis of Heterogeneous, Large Scale Communication Networks for Multi-Element Using Commercial-Off-The-Shelf (COTS) and Government-Off-The-Shelf (GOTS) Simulators	Dr. Albert Legaspi	Space and Naval Warfare Systems Center, San Diego, CA
HPC Framework for Wargaming and Training Simulations	Mr. Larry Patterson	Naval Command, Control and Ocean Surveillance Center, San Diego, CA
Parallelization of the Joint Interim Mission Model (JIMM)	Dr. David Mutschler	Naval Air Warfare Center, Aircraft Division, Patuxent River, MD
Computational Electronics and Nanoelectronics		
Efficient Numerical Solutions to Large Scale Military Tactical Communications Problems via a Scalable Time Domain Method (Sc-MRTD)	Dr. Barry Perlman	Army Communications-Electronics Command, Ft. Monmouth, NJ
Integrated Modeling and Test Environments		
Simulation and Software Implementation of Non-Uniformity Correction (NUC) for Multi-Element Infrared Scene Projector (IRSP) Arrays	Mr. Kenneth Lasueur	Redstone Technical Test Center, Redstone Arsenal, AL
Portfolio EBE, Dr. Barry Perlman, Leader		
Design of Multifunctional Multi-Mode Reconfigurable Antenna Systems for Sensing and Communications	Dr. Gregory Creech	Air Force Research Laboratory, Sensors Directorate, Wright-Patterson AFB, OH
Electromagnetic Environmental Effects Toolkit	Mrs. Rosemary Wenchel	Naval Information Warfare Center, Washington, DC

Table 2. Common HPC Software Support Initiative Projects and Principal Investigators—Continued

Project	Principal Investigator	Organization
Portfolio EBE, Dr. Barry Perlman, Leader continued		
EM Design General Frame Work for 21st Century Integrated Military Platforms	Dr. John Rockway	Space and Naval Warfare Systems Center, San Diego, CA
Portfolio HIE, Dr. Richard Linderman, Leader		
High Performance Computing Software Framework for Hyperspectral Imaging	Dr. George Ramseyer	Air Force Research Laboratory, Information Directorate, Rome, NY
Adaptive Spectral Reconnaissance Program Alogrithms for HPC	Dr. Scott Beaven	Space and Naval Warfare Systems Center, San Diego, CA
Algorithms for Hyperspectral Imaging Exploitation	TBD	
Portfolio SLE, Dr. George Heburn, Leader		
High Fidelity Simulation of Littoral Environments	Dr. George Heburn	Naval Research Laboratory, Stennis Space Center, MS
Multi-Level Parallelization	Dr. Alan Wallcraft	Naval Research Laboratory, Stennis Space Center, MS
Model Integration Framework	Dr. Matthew Bettencourt	Naval Research Laboratory, Stennis Space Center, MS
Simulation of Surf Zone Waves and Currents	Dr. Jane Smith	Naval Research Laboratory, Stennis Space Center, MS
Simulation of Coastal and Esturaine Circulation	Dr. Blain Smedstad	Naval Research Laboratory, Stennis Space Center, MS
Near-Shore Sediment Transport	Dr. Timothy Keen	Naval Research Laboratory, Stennis Space Center, MS
Scalable Modeling of Tidal Reverine Environments	Dr. R.C. Berger	Naval Research Laboratory, Stennis Space Center, MS
Advanced Surface Water-Groundwater Connectivity with Linkage to Atmospheric Outputs	Dr. Stanley Howington	Engineer Research and Development Center, Vicksburg, MS
M&S Environmental Server	Dr. Rick Allard/Dr. William Smith	Engineer Research and Development Center, Vicksburg, MS
Portfolio WTI, Dr. Raja Namburu, Leader		
Penetrator-Target Interaction	Dr. Raju Namburu	Army Research Laboratory, Aberdeen Proving Ground, MD
Blast-Structure Interaction	Mr. Michael Gittrud	Defense Threat Reduction Agency, Alexandria, VA
Optimization of Weapons-Target Systems Design	Dr. Ernest Baker	Tank-Automotive Research, Development and Engineering Center, Warren, MI

Computational Technology Areas

The DoD HPCMP user community is organized around ten broad computational technology areas (CTAs). Each computational technology area has a designated leader who is a prominent DoD scientist or engineer working within the research disciplines included in his or her area. Teams of leading defense scientists and engineers use HPC resources to develop, advance, maintain, and use hundreds of scientific algorithms, codes, models, and simulations needed to analyze, design, develop, test, evaluate, and deploy technologically superior weapons, warfighting capabilities, and related support systems.

Table 3. Computational Technology Areas (CTAs)

Computational Structural Mechanics (CSM) covers the high resolution, multi-dimensional modeling of materials and structures subjected to a broad range of loading conditions including static, dynamic, and impulsive. CSM encompasses a wide range of engineering problems in solid mechanics such as linear elastic stress analysin. CSM is used for basic studies in continuum mechanics, stress analysis for engineering design studies, and structural and material response predictions to impulsive loads.	**Signal/Image Processing (SIP)** emphasizes research, evaluation, and test of the latest signal processing concepts directed toward these embedded system. This will enable the traditional expensive military-unique 'black boxes' required to implement high-speed signal/image processing to be replaced by COTS HPC-based equipment.
Computational Fluid Dynamics (CFD) covers high performance computations whose goal is the accurate numerical solution of the equations describing fluid and gas motion. CFD is used for basic studies of fluid dynamics for engineering design of complex flow configurations and for predicting the interactions of chemistry with fluid flow for combustion and propulsion.	**Forces Modeling and Simulation (FMS)/C4I** focuses on force level modeling and simulation for training, analysis, and acquisition. The acquisition domain includes research and development, test and evaluation, and production and logistics. The overarching Simulation Based Acquisition domain is included.
Computational Chemistry and Materials Science (CCM) covers the computational research tools used to predict basic properties of new chemical species and materials which may be difficult or impossible to obtain experimentally. Within DoD, quantum chemistry and molecular dynamics methods are used to design new chemical systems and solid state modeling techniques are employed in the development of new high-performance materials.	**Environmental Quality Modeling and Simulation (EQM)** covers the high-resolution, three-dimensional Navier-Stokes modeling of hydrodynamics and contaminant and multi-constituent fate/transport through the aquatic and terrestrial ecosystem and wetland subsystems, their coupled hydrogeologic pathways, and their interconnections with numerous biological species.
Computational Electromagnetics and Acoustics (CEA) covers the high-resolution, multi-dimensional solutions of Maxwell's equations as well as the high-resolution, multi-dimensional solutions of the acoustic wave equations in solids, fluids, and gases. Some DoD applications include calculating the electromagnetic fields about antenna arrays, the electromagnetic signatures of tactical ground, air, sea and space vehicles, the electromagnetic signature of buried munitions, high power microwave performance, as well as the interdisciplinary applications in magnetohydrodynamics and laser systems.	**Computational Electronics and Nanoelectronics (CEN)** uses advanced computational methods to model and simulate complex electronics for communications, command, control, electronic warfare, signal intelligence, sensing, and related applications. Use of high performance computing assets enables the DoD electronics' community to solve complex problems, explore new concepts, gain insight and improved understanding of the underlying physics, perform virtual prototyping, and test new ideas.
Climate/Weather/Ocean Modeling and Simulation (CWO) is concerned with the accurate numerical simulation of the earth's climate including the simulation and forecast of atmospheric variability and oceanic variability. CWO includes the development of numerical algorithms and techniques for the assimilation of in-situ and remotely sensed observations into numerical prediction systems.	**Integrated Modeling and Test Environments (IMT)** addresses the application of integrated models, simulation tools and techniques with live tests and hardware-in-the-loop simulations. IMT also provides proof-of-concept by using technology-based war gaming modeling and software integration tools for the simulation of weapon component subsystems and systems in a virtual operational context.

DoD Challenge Projects

Approximately 25 percent of the program's total computational resources are allocated annually to high-priority Service and Agency projects with very large computational requirements. These mission-critical, computationally intensive DoD Challenge Projects are approved by the Deputy Undersecretary of Defense (Science and Technology) (DUSD(S&T)). Proposals are evaluated by the DoD Challenge Projects Allocation Board with representatives from each Service, selected Defense Agencies, and the broader HPC community. The Board selected 42 projects for implementation in fiscal year 2001.

Table 4. FY 2001 DoD HPC Challenge Projects

Project	Sponsoring Organization	Systems
Computational Structural Mechanics		
Damage Simulations in Hard and Deeply Buried Targets Due to Internal Blast and Shock Loading	Engineer Research and Development Center, Vicksburg, MS	IBM SP Cray T3E SGI Origin 2000
Development of Standards for Stand-Off Distance and Blast Walls for Force Protection	Engineer Research and Development Center, Vicksburg, MS	IBM SP Cray T3E SGI Origin 2000
Modeling Complex Projectile Target Interactions	Army Research Laboratory, Aberdeen Proving Ground, MD	SGI Origin 2000 Cray SV-1 Sun E10000
Computational Fluid Dynamics		
3-D Computational Fluid Dynamics Modeling of the Chemical Oxygen-Iodine Laser	Air Force Research Laboratory, Kirtland AFB, NM	SGI Origin 2000 Cray T3E
Active Control of Fuel Injectors in Full Gas Turbine Engines	Army Research Office, Research Triangle Park, NC	Cary T3E IBM SMP SGI Origin 2000
Airdrop System Modeling for the 21st Century Airborne Warrior	Army Soldier & Biological Chemical Command, Natick, MA	Cray T3E SGI Origin 2000
Analysis of Full Aircraft with Massive Separation Using Detached-Eddy Simulation	Air Force Research Laboratory, Wright-Patterson AFB, OH	Cray T3E IBM SP/SMP
Analysis of Infrared Radiance Effects from DivertJet Exhaust Flow Over the Theater High Altitude Area Defense (THAAD) Seeker Window	Space and Missile Defense Command, Huntsville, AL	Cray T90 SGI Origin 2000
Applied CFD in Support of Aircraft-Store Compatibility and Weapons Integration	Air Armament Center, Eglin AFB, FL	SGI Origin 2000
High-Resolution Adaptive Mesh Refinement (AMR) Simulation of Confined Explosions	Defense Threat Reduction Agency, Alexandria, VA	Cray T3E IBM SMP IBM SP
Hybrid Particle Simulations of High Altitude Nuclear Explosions in 3-D	Defense Threat Reduction Agency, Alexandria, VA	SGI Origin 2000
Integrated High Performance Turbine Engine Technology (IHPTET) Combustor Design Studies Using Large-Eddy Simulation (LES)	Air Force Research Laboratory, Wright-Patterson AFB, OH	Cray T3E SGI Origin 2000
Interdisciplinary Advanced Aerospace Vehicle Simulation	Air Force Research Laboratory, Wright-Patterson AFB, OH	IBM SP Cray T3E SGI Origin 2000

Table 4. FY 2001 HPC DoD Challenge Projects—Continued

Project	Sponsoring Organization	Systems
Computational Fluid Dynamics (continued)		
Large-Eddy Simulation of Steep Breaking Waves and Thin Spray Sheets Around a Ship: The Last Frontier in Computational Ship Hydrodynamics	Naval Surface Warfare Center, Carderock Division, Bethesda, MD	Cray T3E IBM SMP Cray SV-1
Multiphase CFD Simulation of Solid Propellant Combustion in Modular Charges and Electrothermal-Chemical (ETC) Guns	Army Research Laboratory, Aberdeen Proving Ground, MD	IBM SP SGI Origin 2000
Numerical Modeling of Wake Turbulence for Naval Applications: Vortex Dynamics and Late-Wake Turbulence in Stratification and Shear	Office of Naval Research, Arlington, VA	Cray T3E SGI Origin 2000
Parallel Simulations of Flow-Structure Interactions	Office of Naval Research, Arlington, VA	Cray T3E IBM SP SGI Origin 2000
Parallel Simulations of Weapons/Target Interactions Using a Coupled CFD/Computational Structural Dynamics (CSD) Methodology	Defense Threat Reduction Agency, Alexandria, VA	Cray T90 IBM SMP SGI Origin 2000
Parallel Structured/Unstructured Simulation of Missile Dynamic Flowfields	Army Aviation and Missile Command, Redstone Arsenal, AL	IBM SP/SMP
Three-Dimensional, Unsteady, Multi-Phase CFD Analysis of Maneuvering High Speed Supercavitating Vehicles	Office of Naval Research, Arlington, VA	Cray T3E SGI Origin/SN1
Time-Accurate Computational Simulations of Ship Airwake for DI, Simulation and Design Applications	Naval Air Warfare Center, Aircraft Division, Patuxent River, MD	IBM SMP
Time Domain Computational Ship Hydrodynamics	Office of Naval Research, Arlington, VA	IBM SP SGI Origin 2000 Cray T3E Cray T90
Unsteady Aerodynamics of Advanced Guided Munitions	Army Research Laboratory, Aberdeen Proving Ground, MD	SGI Origin 2000 IBM SP
Unsteady RANS Simulation for Surface Ship Maneuvering and Seakeeping	Naval Surface Warfare Center, Carderock Division, Bethesda, MD	IBM SP/SMP IBM SMP Cray T3E Cray SV-1 SGI Origin 2000
Computational Chemistry and Materials Science		
Characterization of DoD Relevant Materials and Interfaces	Air Force Office of Scientific Research, Bolling AFB, DC	IBM SP/SMP
Computer Design of Materials from First Principles Theory: A Supercomputer-Based Laboratory	Naval Research Laboratory, Washington, DC	IBM SP IBM SMP
First Principles Studies of SONAR Transducers and Corrosion	Office of Naval Research, Arlington, VA	SGI Origin Sun E10000
Interactions of Chemical Warfare Agents with Acetlycholinesterase	Army Soldier & Biological Chemical Command, Aberdeen Proving Ground, MD	Cray T3E IBM SMP SGI Origin 2000 Sun E10000

Table 4. FY 2001 DoD HPC Challenge Projects—Continued

Project	Sponsoring Organization	Systems
Computational Chemistry and Materials Science (continued)		
Multiscale Simulations of High Temperature Ceramic Materials	Air Force Office of Scientific Research, Bolling AFB, DC	Cray T3E SGI Origin 2000 IBM SP IBM SMP
Multiscale Simulation of Nanotubes and Quantum Structures	Office of Naval Research, Arlington, VA	Cray T3E
New Materials Design	Air Force Office of Scientific Research, Bolling AFB, DC	Cray T3E Cray SV-1 SGI Origin 2000 IBM SMP IBM SP/SMP
Computational Electromagnetics and Acoustics		
Airborne Laser Challenge Project II	Air Force Research Laboratory, Kirtland AFB, NM	Cray T3E Cray SV-1 SGI Origin 2000
Directed High Power RF Energy: Foundation of Next Generation Air Force Weapons	Air Force Research Laboratory, Kirtland AFB, NM	Cray T3E Cray SV-1 IBM SP/SMP IBM SMP SGI Origin 2000
Radar Signature Database for Low Observable Engine Duct Design	Air Force Research Laboratory, Wright-Patterson AFB, OH	SGI Origin/SN1
Climate, Weather, and Ocean Modeling and Simulation		
1/32 Degree Global Ocean Modeling and Prediction	Naval Research Laboratory, Stennis Space Center, MS	IBM SMP
Coupled Environmental Model Prediction (CEMP)	Naval Postgraduate School and Naval Research Laboratory, Monterey, CA	Cray T3E SGI Origin 2000
Coupled Mesoscale Modeling of the Atmospheric and Ocean	Naval Research Laboratory, Monterey, CA	SGI Origin 2000
Data Assimilation in High Resolution Numerical Simulations of the Ocean Circulation	Office of Naval Research, Arlington, VA	Cray T3E
Submerged Wakes in Littoral Regions	Office of Naval Research, Arlington, VA	Cray T3E SGI Origin 2000
Signal/Image Processing		
Automatic Target Recognition Performance Evaluation	Air Force Research Laboratory, Wright-Patterson AFB, OH	SGI Origin 2000
Environmental Quality Modeling and Simulation		
Quantification of the Impacts of Subsurface Heterogeneity on Military Site Cleanup	Engineer Research and Development Center, Vicksburg, MS	IBM SP Cray T3E
Computational Electronics and Nanoelectronics		
Atomistic Simulation of Micro-Electromechanical (MEMS) Devices via the Coupling of Length Scales	Naval Research Laboratory, Washington, DC	IBM SP

Section 2
Success Stories

Air Platforms

Piloted and Unmanned Air Vehicles

Rotary-Wing

- aerodynamics
- flight control
- drive systems
- structures
- subsystems

Aircraft Power

- power generation
- power distribution
- energy storage
- systems integration
- remediation

Joint Strike Fighter—Virtual Strike Warfare Environment

M. Piland

Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River, MD

Impact to DoD: *High performance computers are being used to support service exercises where JSF pilots can fly simulated strike missions in a tactically challenging environment to help them evaluate current JSF concepts.*

Objective

The test objective was to create a high-fidelity, real-time war game environment where tactical concepts can be exercised and investigated for feasibility in defining requirements.

Methodology

VSWE-6 (Virtual Strike Warfare Environment 6) was a joint distributed simulation event with the USAF Joint Expeditionary Force experiment for FY99 (JEFX99). JEFX99 was a Chief of Staff of the Air Force (CSAF) sponsored, Major Command (MAJCOM) executed experiment that combined live-fly forces, live-play ground forces, simulations, and technology insertion into a seamless warfighting environment. HPC was used to process a large, visual database into appropriate textures and images in real-time. This provided a realistic scene that was correlated with the Air Force mission systems distributed simulation. Improved real-time rendering of Power Scene visual databases was provided.

Results

The JSF aviators were given the opportunity to fly simulated strike missions with computer-generated JSFs in JEFX99 in a real time simulation environment that provided a highly detailed, tactically challenging, synthetic environment that represented the threat environment that they would likely encounter in the next century.

Significance

This improved performance provided the warfighters and planners a more realistic environment in which to rehearse the planned missions. This in turn gave the warfighters additional means to evaluate current JSF concepts.

Computer Resources: SGI Origin 2000 and SGI Onyx2 [NAWCAD DC]

CTA: FMS

JWCO: Precision Fires

V-22 Operational Evaluation

L. Huntt

Naval Air Warfare Center Aircraft Division (NAWCAD), Patuxent River, MD

Impact to DoD: *High performance computers were used to simulate a high workload, stressful, high threat environment where V-22 pilots flew simulated Tactical Recovery of Aircraft and Personnel missions to assess the operational issue of survivability.*

Objective

The test objective was to assess the critical operational issue of survivability. A high-fidelity virtual environment was required in order to support realistic operational testing.

Methodology

The V-22 Operational Test (OT-IIE) supported operational evaluation through an integrated virtual scenario. Pilots flew simulated Tactical Recovery of Aircraft and Personnel (TRAP) missions in a high workload, stressful, high threat, synthetic environment that represented the environment that they would likely encounter in the next century. The Aircraft Electronic Warfare (EW) Suite was simulated in a real time environment with realistic threat signatures to provide a hardware-in-the-loop solution.

Results

HPC was used to process a large, visual database into appropriate textures and images in real time. This provided a realistic scene that was correlated with the Simulated Warfare Environment Generator (SWEG) Scenario. Improved correlation of threat terrain masking and improved low level terrain images were provided. This configuration provided for closed-loop effectiveness testing on an installed system using an Advanced Distributed Simulation (ADS) architecture.

Significance

This improved performance provided the operational testers a highly realistic environment in which to assess the critical operational issues of survivability. This also provided data collection of mission parameters critical to augmenting flight test data in addressing this critical area.

Computer Resources: SGI PCA, SGI Origin 2000, and SGI Onyx2 [NAWCAD DC]

CTA: FMS

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Wide-Frequency-Band Antenna Simulation Capability

J.S. Shang, D. Jiao, and J.M. Jin

Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

***Impact to DoD:** High performance computers are being used to develop a wide-frequency-band antenna simulation methodology to design and operate advanced unmanned aerial vehicles and unmanned combat aerial vehicles.*

Objective

Develop the wide-frequency-band antenna simulation capability for unmanned air vehicle (UAV) and unmanned combat air vehicle (UCAV) by solving the Maxwell equation in the time domain. The affordable, design innovation will be further enhanced by using the massive, parallel, data processing software development.

Methodology

The characteristic-based formulation is adopted to solve the time-dependent Maxwell equations for the radiation dominant electromagnetic phenomena. The high-order reconstruction process at the control volume interface, and the fourth-order time advancing scheme, ensures the high resolution numerical simulations. The efficient and scalable performance of the software is obtained from multicomputing systems by the domain decomposition approach.

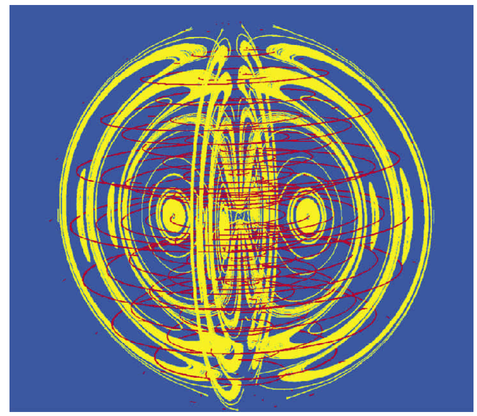


Figure 1. Electromagnetic field of an oscillating electric dipole

Results

The new simulation capability for the wide-band antenna is validated by calculating a center-fed dipole antenna, a monopole antenna, and the electromagnetic interaction with material (Figure 1). The numerical result, depicted here, represents the monopole antenna fed through an image plane from a coaxial transmission line. The antenna is excited by an incident, transverse, electromagnetic Gaussian pulse within the coaxial line. The comparison of the computed and measured voltage reflection in the coaxial line clearly reflects an excellent agreement (Figure 2). The present procedure performed equally well for the linear, center-fed dipole antenna and electromagnetic interaction of coated antenna.

Significance

The critical challenges of UAV or UCAV are the operational communication and control requirements. These functions must be performed faultlessly in different frequencies to meet the mission demand. Unfortunately, the characteristic of an antenna changes drastically with different frequencies. Highly developed traditional simulation methodology in frequency domain is focused on a single frequency simulation. Therefore, new simulation methodology becomes essential for advanced UAV and UCAV design and operation. The present numerical simulation presents a first-ever, numerical description of the time-dependent radiation process in a wide frequency band.

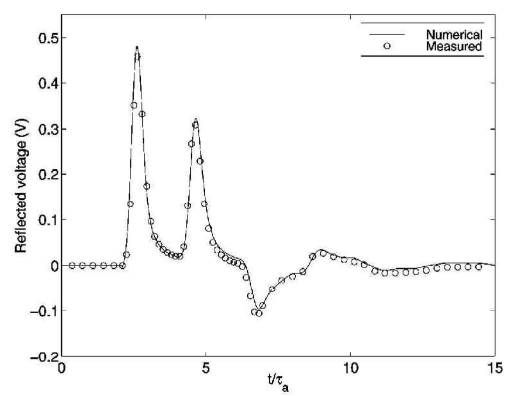


Figure 2. Reflected voltage in the coaxial line for a monopole antenna

Computer Resources: SGI Origin 2000 [ASC MSRC]

CTA: CEA

JWCO: Precision Fires, Electronic Warfare, Information Superiority

Micro Air Vehicle Design

R. Ramamurti and W.C. Sandberg
Naval Research Laboratory (NRL), Washington, DC

***Impact to DoD:**. DoD engineers are using high performance computers to better understand the thrust and lift generation mechanisms in flapping foil propulsion which impacts submersibles, maneuvering, and the aerodynamics of MAVs.*

Objective

Perform three-dimensional numerical simulations of the dynamics of a micro air vehicle (MAV). The proposed studies will investigate the aerodynamic characteristics of MAVs and generation of thrust and lift in flow past flapping airfoils.

Methodology

An implicit finite element solver called FEFLOIC, for three-dimensional incompressible flows based on unstructured grids, is used. The flow solver is combined with adaptive remeshing techniques for transient problems with moving grids. It is also integrated with the rigid-body motion in a self-consistent manner that allows the simulation of fully coupled fluid-rigid body interaction problems of arbitrary geometric complexity in three dimensions. An actuator disk model is employed for modeling the propeller flow. For miniature vehicle propulsion, understanding the insect flight dynamics is very helpful. The unsteady flow past pitching and heaving airfoils, a fundamental mode of propulsion found in many insects, is also simulated.

Results

A numerical model has been developed for simulating the flow past the MAV model developed at NRL, called the Micro Tactical Expendable (MITE) vehicle (Figure 1). The aerodynamic characteristics of this vehicle were computed at several flow angles and control surface configurations. Performance characteristics of another model MITE2, were also evaluated. An actuator disk model was employed to study the effect of the propeller. As shown in Figure 2, simulations were also performed to study the unsteady flow past both pitching, and pitching and heaving airfoils. The effect of varying the frequency of the pitching motion on the thrust generation was studied for two different amplitudes of the pitching motion. This study showed that the variation of the thrust coefficient with respect to the reduced frequency was still dependent on the amplitude of the oscillation, and was independent of the amplitude when viewed with respect to the Strouhal number based on the wake width. Hence, the critical parameter for thrust generation is no the reduced frequency, but the Strouhal number based on the wake width,

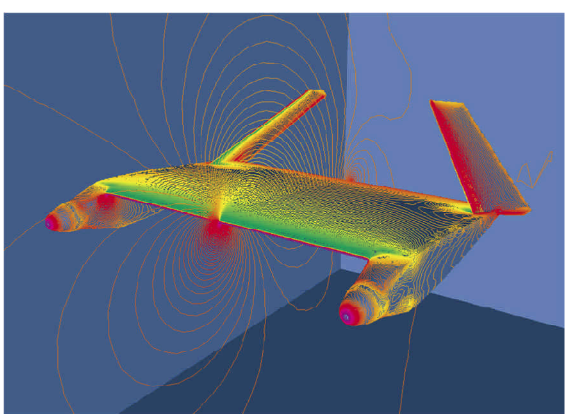


Figure 1. Surface pressure distribution on a micro air vehicle

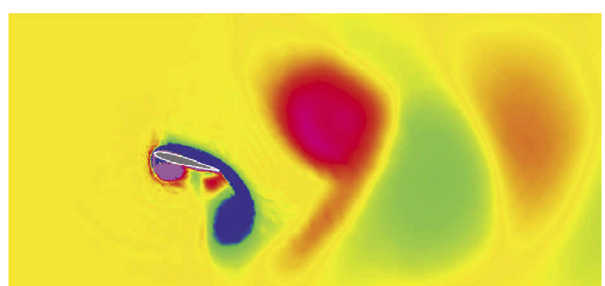


Figure 2. Vorticity contours past a pitching and heaving airfoil

Significance

Simulations have enabled characterization of the performance of MAVs and a better understanding of the thrust and lift generation mechanisms in flapping foil propulsion. The flapping foil propulsion has many applications such as submersible propulsion, maneuvering, and flow control and aerodynamics of unconventional MAVs.

Computer Resources: SGI Origin 2000 [ARL MSRC and NRL DC]

CTA: CFD

JWCO: Electronic Warfare, Information Superiority

Reynolds Number Scaling

W.L. Sickles, D.W. Sinclair, M.L. Laster, and E. Stanewsky
Sverdrup Technology, Inc., Arnold Engineering Development Center (AEDC), Arnold AFB, TN
Deutsche Forschungsanstalt für Luft-und Raumfahrt, Goettingen, Germany

Impact to DoD: *DoD research scientists are making significant strides in the performance predictions of military aircraft.*

Objective

Evaluate CFD capability to predict aircraft flight performance from conventional wind tunnel data obtained at low Reynolds number conditions. Use the results to identify future transonic test facility and computational needs.

Methodology

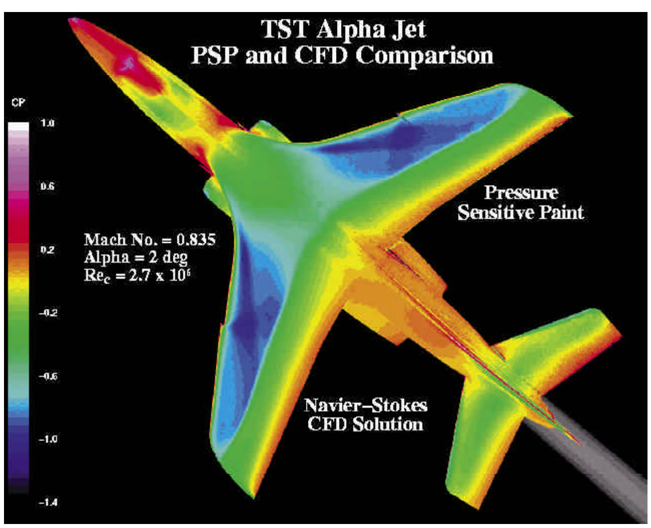
Transonic viscous flow field solutions were computed about the TST Alpha-Jet model for a broad range of Reynolds number, Mach numbers, and angles of attack. The chimera overset grid approach implemented in the NXAIR code was used to compute the flow field results with various turbulence models. The predicted results were evaluated against an extensive set of quality wind tunnel data.

Results

Comparisons with data were good, but CFD did not predict the trends with Reynolds number and the buffet characteristics within accuracy required for future aircraft. The figure below shows a comparison between the CFD predicted pressure distribution and the measured pressure distribution obtained using the pressure-sensitive paint technique. The comparison between the two is excellent.

Significance

The DoD is rapidly expanding its knowledge base of performance information using HPC and varieties of CFD models. This information will enhance future aerospace engineering.



Computer Resources: HP Convex [AEDC DC]
CTA: CFD
JWCO: Precision Fires

Solution on an F/A-18C With Stores in Carriage

R.F. Tomaro, F.C. Witzeman, and W.Z. Strang

Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

Impact to DoD: *Store certification cost and time are being reduced through the use of high performance computers.*

Objective

Demonstration of the accuracy, robustness, and efficiency of a CFD code in predicting the flow field around a complete aircraft with stores.

Methodology

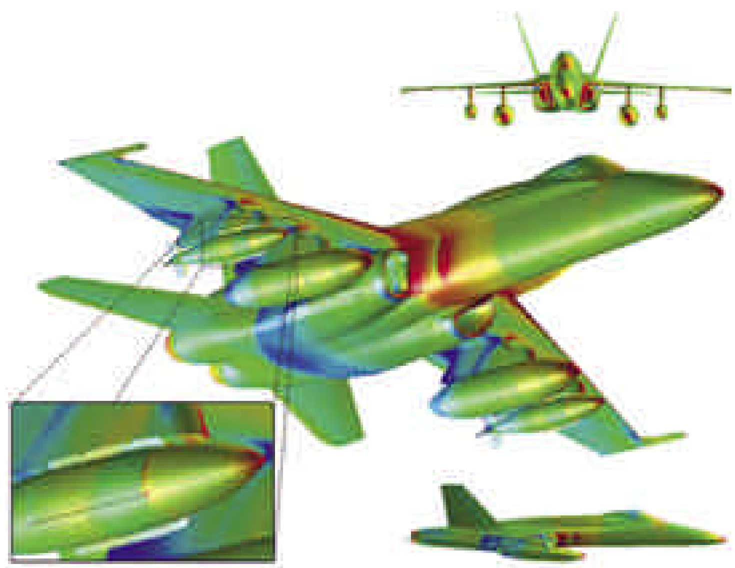
The parallel, implicit, unstructured Euler/Navier-Stokes solver, Cobalt$_{60}$, was used to calculate the flow field around an F/A-18C carrying a 330 gallon fuel tank and a Joint Direct Attack Munitions (JDAM) weapon at two Mach numbers. Specifically, the aerodynamic forces and moments on the JDAM are important for the store certification process. A fully viscous solution was obtained on a grid containing 6.62 million tetrahedral cells. A converged solution was obtained in 5 hours on 232 nodes.

Results

Cobalt$_{60}$ accurately predicted the forces and moments on the JDAM at two flight conditions, M = 0.962 and M = 1.055. Accurate carriage forces and moments are required for accurate store separation trajectory prediction.

Significance

Prior to use in combat, a weapon must be certified for release at a multitude of flight conditions. The aircraft must then be at one of these conditions to safely release that store. Currently, stores are certified by using a combination of wind tunnel tests and flight tests, both of which are very expensive and time consuming. The use of accurate, robust, and efficient CFD codes, in conjunction with wind tunnels and flight tests will be significant in reducing store certification cost and time. Off-body flowfield data will allow us to design better release systems and procedures.



Pressure contours on the surface of the F/A-18C with 330-gallon fuel tank inboard and the JDAM outboard. Flight condition: M = 1.055, Alpha = -0.65, and an altitude of 10,832 ft.

Computer Resources: IBM SP2 [ASC MSRC]

CTA: CFD

JWCO: Precision Fires

Numerical Simulation of a Controlled Store Release From an F-15

A.G. Denny, R.H. Nichols, and K.S. Keen

Sverdrup Technology, Inc., Arnold Engineering Development Center (AEDC), Arnold AFB, TN

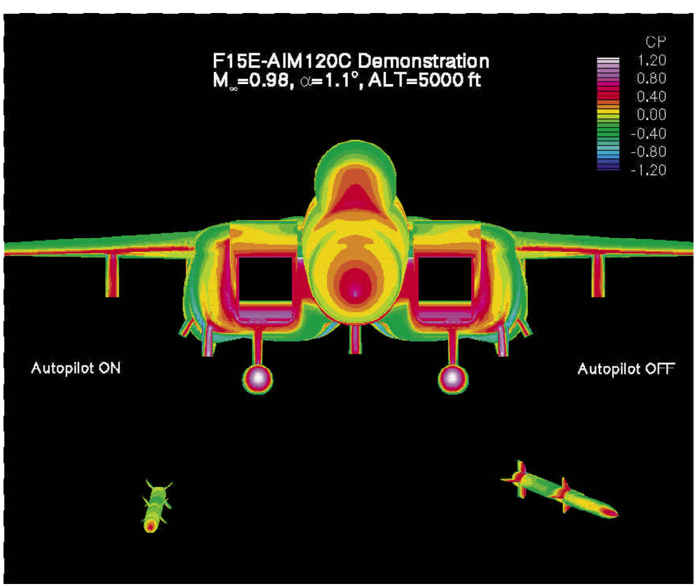
***Impact to DoD:** Using high performance computers to model weapons dropping from various attack aircraft reduces the number of flight tests required to assure the weapon can be dropped safely.*

Objective

To develop and demonstrate the capability to simulate the release of a tactical store munition under the control of an autopilot and moving aerodynamic surfaces. In the typically distorted flow field of a modern fighter aircraft, ensuring safe separation is an increasingly difficult and expensive accomplishment. One major enhancement is to use the store's autopilot to literally fly the store away from the aircraft.

Methodology

To extend AEDC's store separation capabilities, the CFD moving-body capability was modified to include the autopilot code and the ability to move control surfaces on the store in response to sensed accelerations and attitude. Previously, the moving-body capability had been applied only to uncontrolled store release where the store trajectory was completely at the mercy of the aircraft flow field. The new capability accounts for the changes in the store control surface effectiveness caused by the non-uniform flow field of the parent aircraft. The new capability was demonstrated by simulating the release of an AIM-120C Advanced Medium-Range Air-to-Air Missile (AMRAAM) from an F-15E. The computation used the Air Force Office of Scientific Research (AFOSR)-sponsored NXAIR flow solver. The aircraft flow field was treated as inviscid, but the missile flow field was a turbulent Navier-Stokes solution. In the present simulation, the missile is unpowered (no plume). When the missile is attached to the pylon, the autopilot is not active. Shortly after release (6 msec), the autopilot is instructed to sense the current attitude and to maintain or return to that attitude. The free-stream flow conditions are Mach number 0.98, angle of attack of 1.1 deg, and altitude of 5,000 ft (missile length Reynolds of 84.5M). The CFD solution used about 3 million grid points. The solution was accomplished in nine calendar days and represents about 0.5 seconds of real time.



Results

The results include two separate CFD solutions. The right half plane shows the AIM-120C release without autopilot control. The motion of the missile is completely controlled by gravity and the aerodynamic forces on the missile as influenced by the aircraft flow field. The uncontrolled missile immediately undergoes a rapid outward yaw and begins to roll. If the computations were carried far enough the simulated missile would probably enter a tumble. In the left half plane, the missile is under control of the autopilot. It too is forced into a strong yaw, but the autopilot immediately commands furious fin motion to eliminate the yaw, and succeeds in preventing the impending roll. By the end of the simulation, the missile is flying nearly straight and level.

Significance

The new capability has the potential to reduce the number of flight tests required to assure that a controlled store can safely separate from an aircraft in an orientation that will allow successful completion of the weapon's mission. Currently, a flight test for an active AGM-130 store costs on the order of $0.5 million. The new capability allows the degree of control effectiveness degradation to be evaluated and also provides insight as to the causes for the degradation without performing a flight test. This capability will be used to expand the separation envelope of controlled stores from their parent aircraft. This will allow the pilot to release the store at higher speeds and lower altitudes, thus increasing the survivability of the aircraft in a hostile environment and increasing the chances of a successful mission.

Computer Resources: HP Exemplar [AEDC DC]

CTA: CFD

JWCO: Precision Fires

Synthetic Jet Actuators—A Novel Approach to Flow Control

D.P. Rizzetta and M.R. Visbal

Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

Impact to DoD: *The Air Force, using high performance computers, is advancing jet engine technology which will impact flight capability and safety.*

Objective

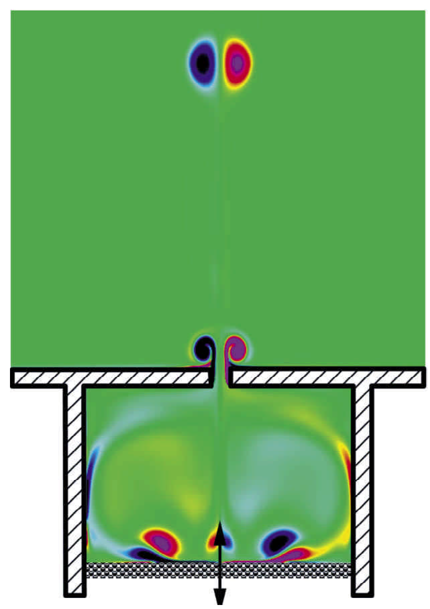
Synthetic jet actuators can consist of an enclosed cavity with a movable boundary that is vented through an opening. As the volume of the cavity is periodically decreased and increased, a series of vortices is generated from the edges of the orifice, which propagate away from the cavity under their own self-induced velocity. These vortices eventually breakdown into chaotic small-scale structures due to spanwise instabilities. The objective of this work is to investigate parameters affecting the performance of these actuators and to predict the observed breakdown so that they may be employed efficiently as flow control devices.

Methodology

Flow fields surrounding synthetic jet actuators are simulated directly by solving the unsteady compressible Navier-Stokes equations. An overset deforming zonal mesh system is used to generate the internal cavity flow, while the exterior jet flowfield is obtained by a high-order, compact finite-difference scheme that is used in conjunction with a non-dispersive spatial filter. Newton-like subiterations of the implicit approximately factored Beaming-Warming algorithm are employed to achieve second-order temporal and sixth-order spatial accuracy.

Results

A series of two-dimensional investigations determined that cavity geometry and Reynolds number played a significant role in vortex dynamics of the actuator flowfield. It was found that previously assumed analytic forms of the jet orifice velocity were incorrect. The three-dimensional, unsteady exterior flow was simulated for the first time numerically, reproducing observed features of the device, including breakdown, which compared well with experimental measurements.



Two-dimensional synthetic jet actuator flowfield

Significance

Because synthetic jet actuators have minimal power requirements and do not require the supply of injected fluid, they are attractive as flow control devices for a number of practical applications. These include managing vortices on aircraft forebodies at high angles of attack, controlling acoustic quality in weapons bays, delaying stall on wings, and increasing lift and decreasing drag on aerospace vehicles. The Air Force, using high performance computers, is advancing jet engine technology which will impact flight capability and safety.

Computer Resources: Cray T90 [ARL MSRC] and Cray C90 [ERDC MSRC]

CTA: CFD

JWCO: Precision Fires

Limit-Cycle Oscillations of a Cropped Delta Wing

R.E. Gordnier and R.B. Melville

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Impact to DoD: *In a resource constrained environment, DoD scientists are using high performance computing resources to expand the capabilities of existing aircraft while minimizing program cost and increasing mission readiness.*

Objective

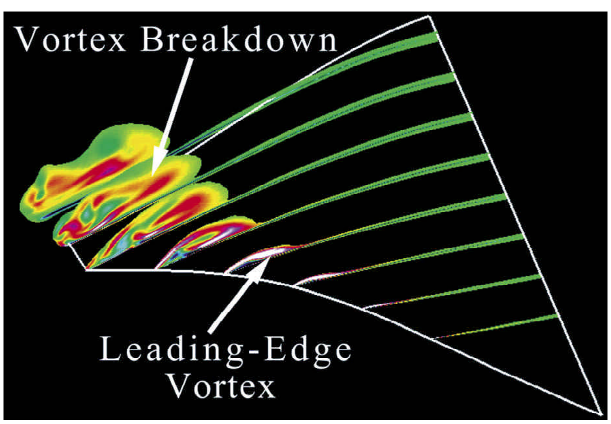
The need to expand flight envelopes and mission requirements for existing aircraft and the design of new flexible and highly maneuverable aircraft has driven interest in developing nonlinear aeroelastic analysis capabilities. Predicting limit-cycle oscillations is one example where classical linear aeroelastic techniques fail and new nonlinear methodologies are needed. This work develops an effective nonlinear prediction capability for the simulation of complex aeroelastic phenomena.

Methodology

A CFD scheme which solves the unsteady, three-dimensional, full Navier-Stokes equations is implicitly coupled with a general, linear, structural solver through the use of subiterations. The resulting scheme is second order accurate in both time and space and satisfies the Geometric Conservation Law. Efficient implementations have been achieved on vector platforms as well as on massively parallel systems using a domain decomposition strategy. The method is well suited for simulating aeroelastic problems involving the nonlinear aerodynamic mechanisms involved in limit-cycle oscillations.

Results

Successful simulations of the limit-cycle oscillation of a cropped delta wing have been achieved with qualitative agreement of experimental measurements being obtained. Analysis of the computed results indicate that the aerodynamic mechanism that gives rise to the limit-cycle is the development of a leading-edge vortex. This vortex acts like an aerodynamic spring limiting the growth of the structural oscillations.



Leading-edge vortex structure during the limit-cycle oscillation of a cropped delta wing

Significance

Due to the minimal number of new aircraft being produced, the Air Force is using its aircraft for new missions not considered in their original design. Examples of these changes include new missions or flight envelopes, changes to pilot practices, or the addition of new stores. These changes can result in unforeseen aeroelastic behavior such as limit-cycle oscillations. Aeroelastic challenges can also arise in the design and manufacture of new aircraft. The ability to accurately simulate the resulting complex fluid/structure interactions involved in these situations is important in identifying and minimizing the impact of these problems on program cost and mission readiness.

Computer Resources: Cray T90 [ARL and NAVO MSRCs] and IBM SP2 [ERDC and ASC MSRCs]

CTA: CFD

JWCO: Precision Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

Simulation of the V-22 Tiltrotor Aircraft in High-Speed Cruise

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Impact to DoD: *Using high performance computing resources, DoD engineers are able to conduct unprecedented design-to-flight analysis for general tiltrotor aircraft. This will enable the DoD to more affordably evaluate future tiltrotor concepts.*

Objective

To accurately simulate a roto wake system to predict rotor airframe interaction and aircraft acoustics.

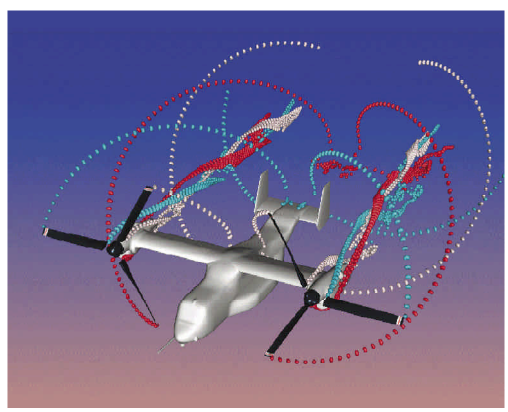
Methodology

The V-22 tiltrotor aircraft is strategically significant in both a defense and civil sense. The present simulation corresponds to a high-speed cruise condition for which flight data exists. A future wind tunnel experiment is scheduled that includes this case as a data point. The specific case corresponds to a full-span tiltrotor at Mach 0.445, 4.3 degrees angle-of-attack, flying at an altitude of 14,930 feet and -2.8 degrees Celsius. The rotor-blade collective pitch angle is 45.1 degrees at 75% radius. The rotor speed is 333 rpm.

Overset structured grid methods and software from the CHSSI CFD CTA are used to discretize and simulate the flow for the V-22 tiltrotor aircraft. Grid components conform to the shape of the V-22, facilitating resolution of the viscous boundary layer and important off-body aerodynamics. The near-body portion of the V-22 geometry is decomposed into 118 components. The off-body grid system includes 150 components. The full-span V-22 aircraft, including the forward looking infrared (FLIR), AAR47 sensor, refueling boom, engine nacelle, rotor spinner, blades, and tail section are directly represented in the grid system.

Results

A time-accurate result for the V-22 high-speed cruise case is obtained for a period of 4 rotor revolutions. Temporal resolution of the event is realized with 2,000 time-steps per revolution. Nearly 30 million grid points are used to spatially resolve the problem domain. An important result of the simulation is the capture of the rotor tip vortices as part of the solution. As indicated in the figure, the vortices are evident in the field a full body length downstream of the rotors.



The V-22 rotor-wake system is visualized in a post process where filaments of particles are released from inboard and outboard blade-tips every 25 time-steps

Significance

This result is significant in several respects. Accurate simulation of the rotor wake system is important for predicting rotor-airframe interactional dynamics as well as aircraft acoustics. Combined with existing flight data and scheduled tunnel data, the result provides the basis to demonstrate design-to-flight analysis capability for general tiltrotor aircraft. The result is a high-fidelity baseline data set that can be used to evaluate future tiltrotor concepts such as variable-diameter tiltrotors, quadrotors, and Joint Transport Tiltrotor configurations.

Computer Resources: IBM SP and Pandion (65-nodes) [ERDC MSRC]

CTA: CFD

JWCO: Information Superiority, Precision Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

CFD-Based Rotorcraft Improvement Studies

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Impact to DoD: *The Army is using high performance computers to predict the loads, performance, and acoustics of rotor aircraft in various modes of operation allowing them to improve rotor aircraft designs and to answer the question of whether to field new aircraft or modernize the existing fleet.*

Objective

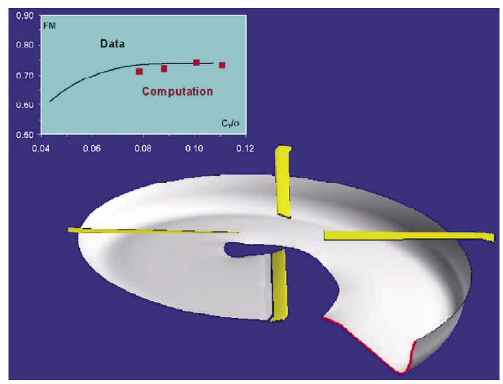
This work is an Army computational project concerning the aerodynamic prediction of the loads, performance, and acoustics of rotorcraft in various modes of operation. Much of the effort supports design and development work leading to modernization of currently operational rotorcraft. Other work supported includes loads correlation and validation studies aimed at improving current predictive ability. This is essential to the design of new and more highly optimized helicopters and tiltrotor aircraft. The primary problem in this work is the long-term inability to predict rotor wake flows to high accuracy. These difficulties, which are both physical and numerical, are a major cause of the cost and risk of rotorcraft development. Another goal is the development of new ways to predict these flows.

Methodology

The problem with solving wake flows numerically is that the discretization process produces an artificial dissipation that ruins solution accuracy. The usual remedy nearly always involves increasing the grid density, which is very expensive. This work is unique in that it does not rely on grid densification. The method of vortex embedding uses a potential flow solver to compute the wake region. This particular potential solver allows wake sheets to lie anywhere within a grid and this permits the use of a straightforward wake marker convection, which is dissipationless. The wake solver is then coupled to a Navier-Stokes solver that computes the local flow on the surface of the rotor blade. Another sparse-grid method for predicting rotor-fuselage flows, "vorticity confinement", is also under active development.

Results

The enclosed figure shows a typical computed wake sheet (using the embedding method) that is shed from a rotor and the resulting comparison of predicted and measured performance. Because the sheet is composed of discrete flow particles, it does not dissipate at all. (The figure shows a small part of the wake, but it actually can convect indefinitely.) The inset shows a resulting plot of rotor power vs. lift—both measured and computed for the UH-60A Blackhawk helicopter. The comparison is very good—in fact, it is closer than the typical experimental measurement error.



The computed wake of the UH-60A, Blackhawk Helicopter and a comparison of the computed performance with measurement

Significance

These results have been obtained with grids that are 1/100 to 1/1000th the size of those required using conventional CFD methods. The present methods are currently in use in configuration design efforts (the only CFD method to be so used for wake problems) and this will permit the development of optimization methods. The resulting improved design will permit helicopters to carry significantly more payload for a given engine.

Computer Resources: Cray C90 [ERDC and NAVO MSRCs]

CTA: CSM

JWCO: Force Projection/Dominant Maneuver

CFD Analysis of Surge and Rotating Stall Control in Compressors

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Impact to DoD: *DoD scientists are using high performance computers to overcome engine failure from surge and stall.*

Research Objectives

To develop efficient CFD methodolologies for modeling unsteady phenomena (surge and rotating stall) in axial and centrifugal compressors and perform numerical studies of active stall and surge control strategies (air injection, bleed valves).

Methodology

A three-dimensional, unsteady viscous flow code called GTTURBO3D has been developed which solves the three-dimensional unsteady, compressible, time-averaged form of the Navier-Stokes equations in finite volume form.

Results

The code was applied to low- and high-speed axial and centrifugal compressors and validated. At reduced mass flow off design conditions, local reversed flow was first found to occur in the leading edge region of the impeller blades. If left unchecked, this reversed flow region grows spatially and temporally, eventually resulting in surge. Injection of air at the compressor face and bleeding air from the diffuser were found to be effective methods for the elimination of surge, and for extending the useful operation range of the compressor.

Significance

The stable operating range of compressors is limited at low mass flow rates by the occurrence of aerodynamic flow instabilities, rotating stall, and surge. These instabilities can cause considerable fatigue and damage to the entire compression system, creating engine failure. Calculations show that air injection and bleeding air significantly extend the operating range of a compressor and restore a system experiencing surge to a safe condition.

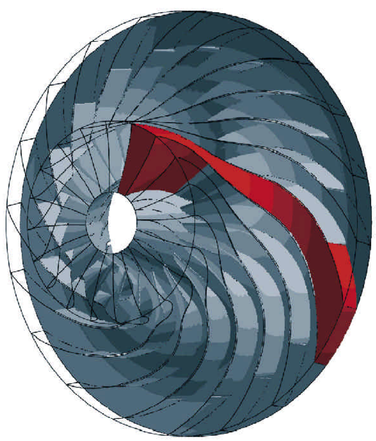

Figure 1

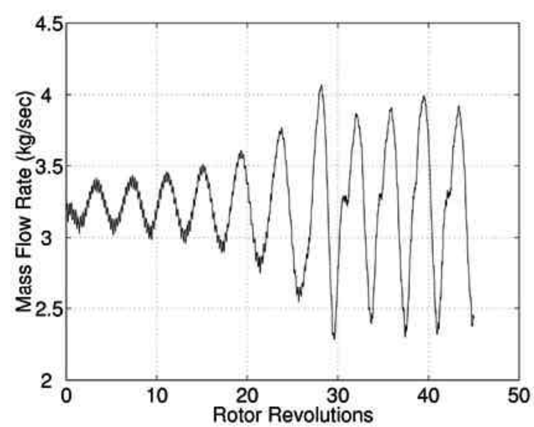

Figure 2

Computer Resources: SGI Origin 2000 [ERDC MSRC]

CTA: CFD

JWCO: Precision Fires

Information Systems Technology

Integrated and Unified DoD S&T Investment Strategies

Information Superiority

- dominate and control battlespace
- developing applications
- supporting architectures
- warfighter operational training
- concept development
- system acquisition

Parallel Electromagnetic Solvers for High-Frequency Antenna and Circuit Design

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B. Perlman

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Impact to DoD: *DoD engineers are using electromagnetic solvers on high performance computers to digitize the battlefield and develop secure communication systems.*

Objective

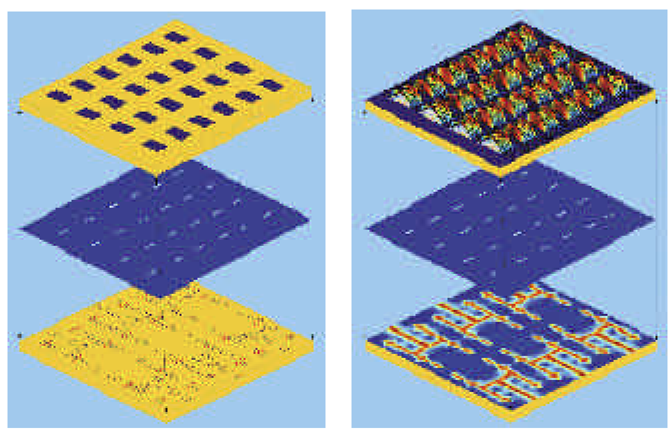
To develop linearly scalable parallel electromagnetic (EM) solvers for large multi-layered antenna array systems and complex three-dimensional microwave/millimeter-wave circuits. Fast and accurate characterization of these electromagnetic structures is of critical importance for a successful DoD mission in digitizing the battlefield and developing secure communication systems.

Methodology

The hybrid finite-element (FEM)/method-of-moment (MoM) numerical technique is developed for the design and characterization of multi-layered antenna array circuits. This technique combines the MoM solution of the radiating domain with the FEM solution of the feeding network. The two domains are coupled through the boundary condition between two regions to provide the solution of the problem under study.

Results

The parallelized hybrid FEM/MoM code has demonstrated linearly scalable performance improvement and the matrix-decomposition strategy for the hybrid FEM code allows the solution of problem with millions of unknowns. The number of unknowns of the 4x6 antenna array example ranges from 1,800,000 to 2,100,000 in the FEM matrix and from 4,800 to 6,600 in the MoM matrix. The computation results include input impedance of the antenna system and far-field radiation patterns. The software has the potential to be used in various types of antenna problems that have a large number of antenna array and arbitrary-shaped multi-layered complex feeding network.



The figures show the geometry of 4x6 double-layered slot-coupled antenna array system and the computed magnetic and electric field distributions on feeding network and patch antenna array.

Significance

It is of critical importance to characterize and design a high-frequency multi-layered antenna array system with a large and complex geometry for the development of advanced military radars and communication systems.

Computer Resources: IBM SP [University of Michigan CPC] and SGI Origin 2000 [NCSA]

CTA: CEN

JWCO: Electronic Warfare, Information Superiority

Advanced Virtual Intelligence, Surveillance, and Reconnaissance (ADVISR)

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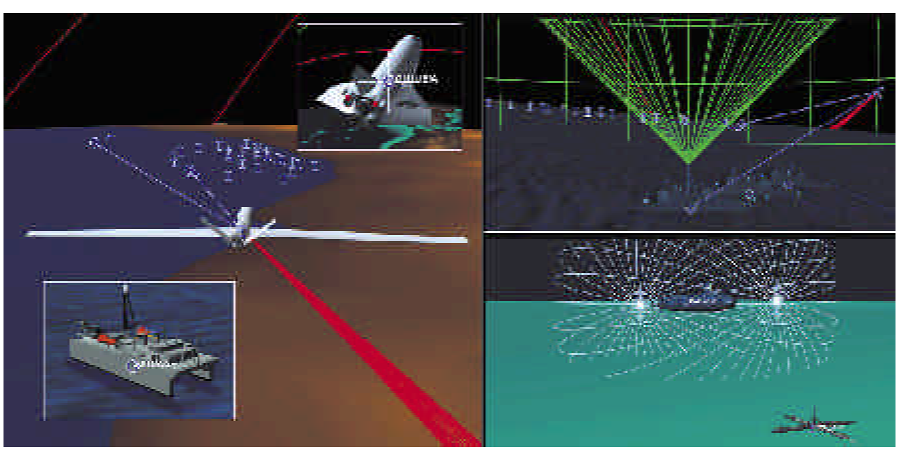
Impact to DoD: *High performance computers and high-bandwidth, low-latency, networking technologies provide a capability to virtual prototype real-time systems and metasystems impacting military sensors, communication, and C2 systems. The technology supports simulating air traffic control communication, drug-enforcement surveillance, and port monitoring.*

Objective

To develop scalable, portable, HPC software that provides the capability to design, build, and test systems and metasystems (systems of systems) in virtual reality.

Methodology

High performance computers and high-bandwidth, low-latency, networking technologies provide a capability to virtual prototype real-time systems and metasystems. ADVISR system elements are designed to be performance and interface equivalent to their real counterparts so that real hardware and software components can be substituted for virtual components as concepts and designs evolve. Systems can initially be designed, developed, and tested in diverse modes including all-virtual domain and virtual-real combinations. Furthermore, these systems can be laboratory tested before field testing using the virtual environment to stimulate prototype engineering-development-model and production systems. Real-time, physics-based models are used for virtual-reality prototyping of sensor, communication, data-fusion, command-and-control (C2), and other types of systems. HPC is required for real-time calculation of: target tracks; source spectral energies; propagation loss from multiple sources to multiple sensors through multiple paths as a function of frequency; environmental and instrument noise; sensor signal processing, data funsion, and report generation; and inter-node communication through virtual transmitters and receivers (acoustic and RF). ADVISR includes a real-time, three-dimensional, round-earth, visualization environment that allows the user to visually correlate and provide multi-aspect views of entity positions and orientations, terrain and bathymetry, raster-map, satellite photo-reconnaissance, and Digital Chart of the World data, as well as non-visual effects such as antenna patterns, sensor sensitivity volumes, link connectivities, environmental data, and satellite orbits. ADVISR is implemented on a heterogeneous network of machines. The Hewlett-Packard (HP) V2500 is linked to an SGI Onyx2 visualization computer by a dedicated fiber-optic High Performance Parallel Interface (HIPPI). An ATM switch links the HP V2500 to local classified assets and to other HPC assets, where ADVISR processes can run, over the DREN. System elements and Graphical User Interfaces (GUIs) are implemented as portable and scalable Parallel Virtual Machine (PVM) processes and named mailboxes to



System Virtual Prototyping, a screen capture from the ADVISR real-time, three-dimensional visualization system *allow asynchronous startup and connections. As software technology evolves, the ADVISR software will transition to a Message Passing Interface (MPI), Interoperable MPI (IMPI), and MPI Real Time (MPI-RT) implementation. ADVISR is now a Distributed Interactive Simulation (DIS) compatible system that will be converted to the Defense Modeling and Simulation Office (DMSO) High Level Architecture (HLA).*

Results

ADVISR is being used to virtual prototype the Deployable Autonomous Distributed System (DADS). This is a wide-area networked field of low-cost sensors that can operate in an undersea environment (in conjunction with distributed undersea weapons) to detect, locate, classify, and neutralize the quiet submarine as a potentially dominant threat in littoral warfare. Sensor and master nodes are implemented using Advanced Development Model software stimulated by virtual magnetic and acoustic sensors. Virtual acoustic data links are used for inter-node communication with virtual RF communication links used to transfer data to real C2 systems.

Significance

Virtual systems have the potential to (a) evaluate system concepts and architectures; (b) test and optimize complex systems before building them with external system elements and warfighters-in-the-loop; (c) provide early detection and correction of design and development problems by early testing using specification, design, and measured data, as well as real hardware and software, as available; (d) provide training and mission rehearsal capabilities; and (e) evaluate the effectiveness of system modifications. Although originally intended to support military sensor, communication, data fusion, and C2 systems, ADVISOR's technology is also able to support the simulation of air-traffic-control and collision avoidance; commercial ground, air, and space communication; drug-enforcement surveillance operations; commercial port monitoring; airport acoustic noise level planning; border monitoring, and other systems.

Computer Resources: HP V2500 [SSCSD DC)

CTA: IMT

JWCO: Information Superiority, Combat Identification, Joint Readiness and Logistics and Sustainment of Strategic Systems, Military Operations on Urbanized Terrain

Virtual Wind Tunnel for Virtual Prototyping and Design

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University of Colorado, Boulder, CO

***Impact to DoD:** The design of composite structures which will be used in next generation aeronautical engineering is being enhanced through the use of virtual wind tunnels for virtual prototyping and design.*

Objective

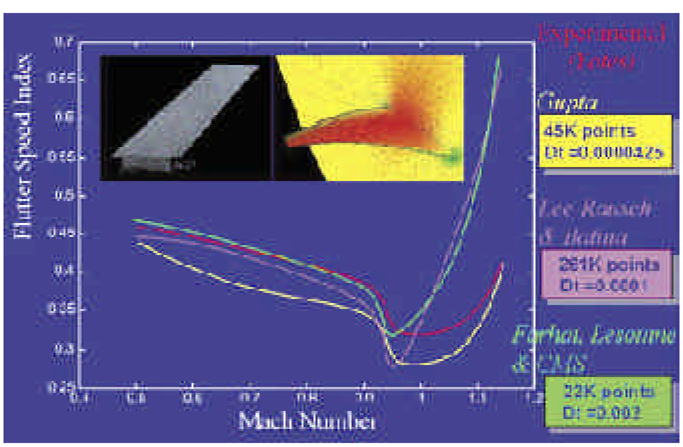
To investigate the feasibility of performing distributed meta-computing across machine and site boundaries for coupled "grand challenge" problems that involve multiphysics formulations. To establish structure-fluid interaction simulation infrastructure on NRL's ATM network of HPC systems as a demonstration site of the concept, under the framework of a virtual wind tunnel through validated simulation, for the needs of virtual prototyping and design. To perform sensitivity, scalability, and efficiency analysis for such an approach and establish the framework for world wide web (WWW) access of this technology for realistic applications.

Methodology

The University of Colorado's "Finite Element Tear and Interconnect" (FETI) algorithms were used for domain decomposition and solution of large, realistic-size, coupled, aero-structural problems. NRL's composite material characterization methodology was used based on the experimental identification of material constitutive response, to extend into general multiphysics nonlinear materials and structural interaction with the fluid.

Results

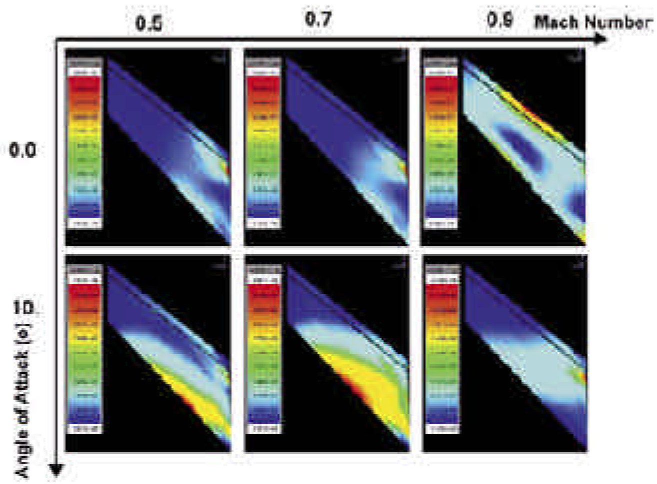
The numerical simulations were validated through successful comparison with experimental wind tunnel data, for the case of the AGARD wing 445.6. An infrastructure was established for computing dissipated energy density distributions as a measure of the health of the material and its nonlinear behavior due to structure-fluid interaction loading. Computed distribution of dissipated energy density have be performed for the AGARD wing for a variety of mach numbers and angles of attack.



Flutter Index vs. mach number for the AGARD wing 445.6. Comparison of experimental with various numerical solutions of the fluid problem. The green line reflects the present approach of fluid-structure interaction through the FETI method.

Significance

Virtual prototyping and design of composite structures, under realistic loads imposed from the fluid-structure linear and non-linear interaction, is of paramount importance to the cost and mision efficiency for the design of composite structures. It is anticipated that structures designed through the use of a virtual wind tunnel, along with the accurate composite material characterization, will have a direct and high impact on the manufacturing precision and demanding tolerances required for increased Precision Fires capability.



Dissipated energy distributions on the top surface of the composite AGARD wing, for various combinations of angle of attack and mach number. Computations have been performed with full structure-fluid interaction coupling implementation.

Computer Resources: SGI Origin 2000 [NRL DC]
CTA: CSM
JWCO: Precision Fires

Materials/Processes

Hardware, Platform, and Infrastructure

Materials and Processes

- pollution prevention
- adaptations to manufacturing
- refurbishment
- disposal processes
- quality of the environment
- resource conservation
- remediation

Embedded Applications for Signal/Image Processing

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Impact to DoD: *DoD will enjoy long term benefits from the parallelization of SIP codes under CHSSI.*

Objective

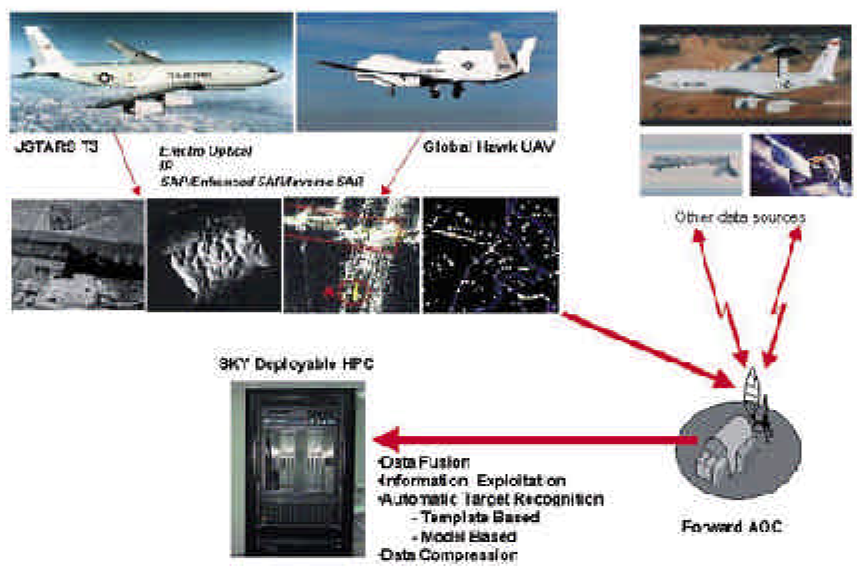
To develop reusable signal processing code modules that are efficient, scalable, and portable across a diverse group of HPC architectures. The modules include two-dimensional FFT, Clutter Characterization, Space-Time Adaptive Processing (STAP), and a parallel data fusion tracker.

Methodology

The STAP, parallel data fusion tracker, and clutter characterization codes of interest were developed internally at the Air Force Research Laboratory/Rome Research Site for use in on-going, real-time data collection and analysis programs. These codes were serial and very specific to the application. The two-dimensional FFT was developed as a generic code that could easily replace its serial version in existing code. Under CHSSI sponsorship, these codes were analyzed for the ability to be parallelized without degrading performance. All codes were written in standard ANSI C or Fortran, with MPI the desired communication interface. A tradeoff was made between performance and portability. For this set of codes, portability was deemed the most important feature, so code efficiency relied on commercial-off-the-shelf (COTS) optimized math libraries, foregoing the use of assembly language.

Results

Independent testing of the ported codes showed that performance for each module increased linearly with the number of processors assigned to the task. This increase was independent of the platform topology, showing that portability and scalability were achievable in a generic, i.e., non-machine specific, software package. The codes were documented in a User/Technical Manual, test suites and installation scripts written, and sample output results provided for each package.



Significance

Having a library of usable, portable, and scalable signal processing codes takes the onus of writing such modules from the code developer and decreases development/deployment time. Such portability allows the code to be deployed on many different platforms, whether embedded or not, and realize a known level of performance.

Computer Resources: Intel Paragon [AFRL DC, Caltech], IBM SP2 [NWU, Argonne National Laboratory], Cray T3E [SDSC], and SGI Origin 2000 [NWU]

CTA: SIP

JWCO: Information Superiority, Combat Identification

Verification of Theory for Dispersion of Groundwater Contaminants

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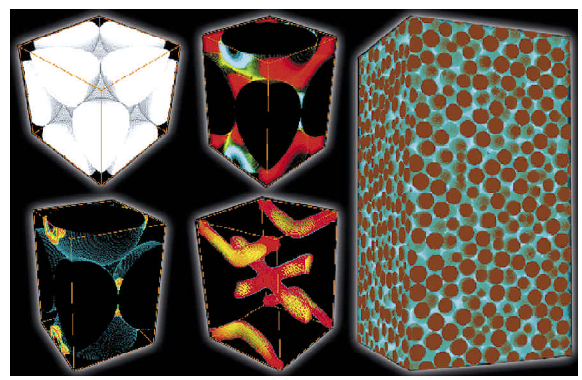
Impact to DoD: *DoD scientists are using high performance computers to simulate the transport of contaminants through natural aquifiers.*

Objective

There is a vital need for effective remediation procedures to mitigate effects of contaminant spills at DoD facilities. Site assessment, design of remediation procedures, monitoring of remediation work, and proof of effectiveness all depend on an ability to characterize the transport of contaminants through natural aquifers. Unfortunately, groundwater transport theory remains the limiting factor in the accuracy of groundwater models. The understanding of transport processes has been enhanced through virtual laboratories based on very-large scale computer experiments made possible by the DoD HPC resources. These experiments, combined with theory on non-local continuum, provide an opportunity to field a practical groundwater model.

Methodology

Two discrete methods are combined to simulate pore-scale flow and mass transport. The first method simulates fluid flow, using a discrete Boltzmann equation on a lattice. The lattice-Boltzman method recovers Navier-Stokes behavior in the low Mach-number regime. The second method simulates the movement of a tracer in the bulk fluid flow, using a Langevin equation. The Langevin equation models the motion of a discrete particle as a function of the local fluid velocity and a random force representing molecular diffusion.



Simulated porous media showing close up of flow field components

Results

The virtual experiments demonstrate the relationship between dispersion and the multi-scale velocity correlation, which is the basis of non-local transport theory. The experiments also suggest that macroscopic dispersion rates are lower than reported in earlier literature.

Significance

The work is particularly relevant because simulated experiments were performed that, for the first time, accurately replicated the geometry of the pore space in a domain large enough to observe the non-Fickian evolution of plume growth. Thus, a method for simulating previously unattainable subsurface features that strongly influence the transport and diffusion of contaminated materials has been formulated that is both accurate and computationally efficient. The resulting simulations provide a means to provide a cost effective and efficient means to more accurately optimize remediaiton scenarios at formerly used defense sites and active DoD installations. This work is being done as a DoD Challenge Project.

Computer Resources: IBM SP2 [ERDC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Resin Impregnation Process Simulations for Joint Strike Fighter (JSF) Aerospace

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K.K. Tamma, R. Kanapady, and N.D. Ngo

University of Minnesota, Minneapolis, MN

***Impact to DoD:** DoD scientists are developing high performance computer simulations to streamline and reduce new composite weapon system development and acquisition.*

Objective

To develop computational techniques, scalable computational software, and tools for high performance computing simulations applied to resin impregnation and transport phenomena during composite manufacturing processes. Computer simulations reduce both the time and cost associated with manufacturing various new composite weapon systems. These developments provide enabling simulation technologies to streamline the acquisition process and reduce costs through the Simulation Based Acquisition (SBA) and Simulation Modeling, Acquisition, Requirements and Training (SMART) paradigms. Applications relate to technology transitions for the improved manufacture of actual composite structural components in JSF (Figure 1).

Methodology

The large-scale composite structures in JSF, with their associated physical and geometrical complexities, are manufactured by net-shape composite processing techniques such as resin transfer molding and its variants. Computational techniques and process simulation capabilities have been developed by the University of Minnesota and the U.S. Army Research Laboratory to understand the resin progression behavior inside complex mold cavities filled with heterogeneous, fibrous, porous media (Figure 2). The permeating polymeric resin consolidates the fibrous reinforcing media producing complex, load bearing composite structures. Physics-based process simulations aid engineers in modeling various processing parameters and the manufacturing and mold conditions in a virtual environment to determine the optimal conditions for production. The process simulations reduce time and cost involved in the trial-and-error based approaches. This leads to reduced time for process maturation and limits the developmental costs through integrated and synergetic design and process development phases during the acquisition cycle (Figure 3). The process simulations are based on pure finite element formulations employing a transient resin mass balance to analyze

Figure 1. Joint Strike Fighter

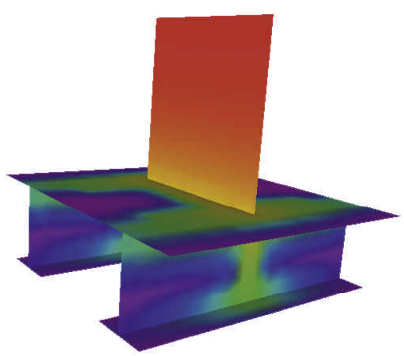

Figure 2. Temporal resin progression contours

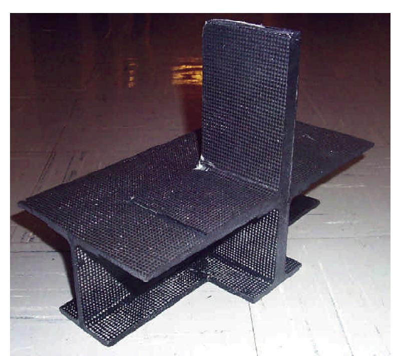

Figure 3. Risk reduction article

the various transport phenomena and the transient resin propagation and distribution through complex two-dimensional and three-dimensional mold cavities. Scalable software developments are based on efficient parallel implementation. Both domain decomposition approaches and data parallel approaches have been employed. The integrated computational developments and simulation analysis capabilities with associated graphical user interfaces have been named OCTOPUS-COMPOSE.

Results

The developments have been used to simulate the resin propagation behavior in JSF composite structural components (Figure 4). The process simulation predictions matched well with actual behavior in risk reduction articles. The figures illustrate the temporal resin propagation behavior in two different JSF composite structural components. The new computational developments and the pure finite element technique employed in these simulations is now providing accurate large-scale process simulations for prediction of behaviors under operational load conditions.

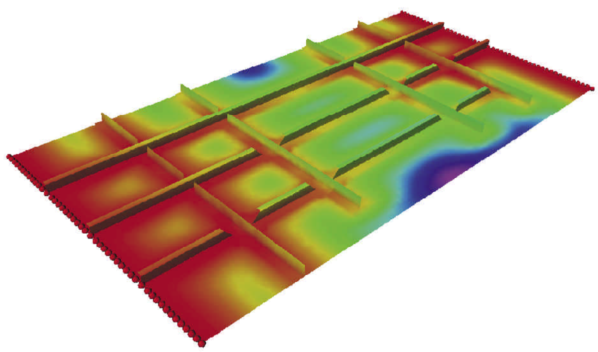

Figure 4. Complex panel temporal resin progression contours

Significance

The computational simulation capabilities streamline and reduce new composite weapon system development and acquisition, thus reducing cost and time for development and deployment. These developments provide the enabling technologies for various defense and dual-use programs such as the Manufacturing Technology Objective and Composite Affordability Initiative, tailored to strengthen the industrial technology base in composite manufacturing. The multi-physics, multi-scale phenomena in the processes have generated significant basic research in various facets, thus improving the understanding of the process as well as providing solutions currently seen during the manufacture and use of composite structural components.

Computer Resources: SGI Origin 2000 [ARL MSRC] and Cray T3E [AHPCRC DC]

CTA: IMT

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Three-Dimensional Groundwater Modeling for Determination of Environmental Impacts Associated With Deep Underground Mining

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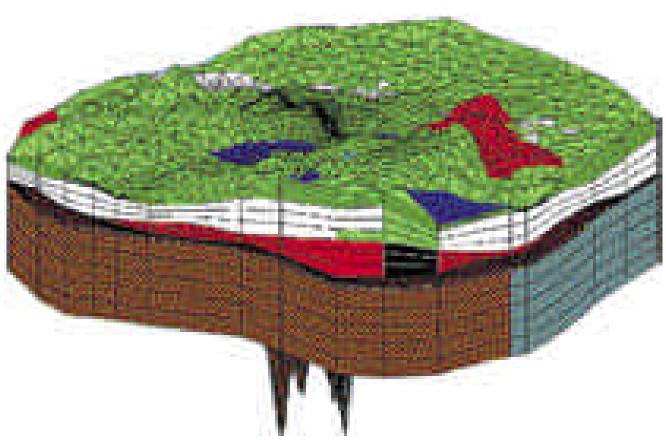
Impact to DoD: *DoD scientists have developed a three-dimensional groundwater modeling capability to run on high performance computers that allows scientists to model a class of problems that were previously unsolvable.*

Objective

To develop three-dimensional groundwater modeling capability that can be applied to large, computationally-intensive unstructured finite element meshes over model long (e.g., decades) simulation periods.

Methodology

FEMWATER, a three-dimensional finite element groundwater flow and transport code that simulates both saturated and unsaturated groundwater flow, is a primary tool for groundwater analysis in the Department of Defense Groundwater Modeling System. A version of this code that enables parallel processing, through the use of message passing and grid partitioning, was developed and implemented. The DoD, through the U.S. Army Corps of Engineers, is charged with stewarding many of the nation's water resources and their adjacent environments. As part of an environmental impact statement, questions concerning groundwater impacts to wetlands, streams, and lakes often must be addressed. As an example, a large, highly-resolved finite element mesh has been required to model the groundwater and wetland changes that may result from the operation of 2000-foot-deep mine located under approximately 250 feet of glacially-deposited sediments. Evaluation of potential impacts of mining operations were conducted for a 28-year simulated period. Computational accuracy was stressed because of the potential that lowering the groundwater table even several inches would cause significant changes to sensitive wetlands, streams, and lakes located near the proposed mining area. FEMWATER, which was developed in part under the auspices of the CHSSI, is the only means possible to perform this detailed study.



Head difference with mine and without mine. Blue represents less that 2 feet difference; red represents 20 feet difference.

Results

The parallel version of the FEMWATER code was developed and has been implemented for a variety of military and Army civil works applications. For one Army civil works application, the model was calibrated and predictive runs were made to assess the potential impacts of mining activities on adjacent wetland resources. The predictions indicated that the groundwater drawdown will reduce a number of wetland areas while having a lesser impact on area streams and lakes. The parallel capability provides the ability to model a class of problems requiring large, highly-resolved unstructured meshes that previoulsy were unavailable. The ability to provide better physics to a complex problem with fewer assumptions resulted in more defensible results.

Significance

Without these resources, simplifying assumptions would have been necessary and inaccurate conclusions could have been reached regarding the potential impacts of mining to the adjacent water resources. Additionally, use of FEMWATER for applications such as this point to the exceptional dual-use capabilities that this (and other) CHSSI developments have in support of both military and civilian concerns.

Computer Resources: Cray T3E, IBM SP [ERDC MSRC] and IBM SP3 [ASC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Dynamically-Coupled Surface Water and Groundwater Modeling in Everglades National Park and South Florida

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Impact to DoD: *DoD scientists tested a new surface water and groundwater modeling capability by using high performance computers to run a 1-year simulation for the Southern Florida Ecosystem in less than 8 hours. This makes it possible to accurately simulate potential management scenarios within highly complex wetland environments common to DoD-managed land and non-military lands of interest.*

Objective

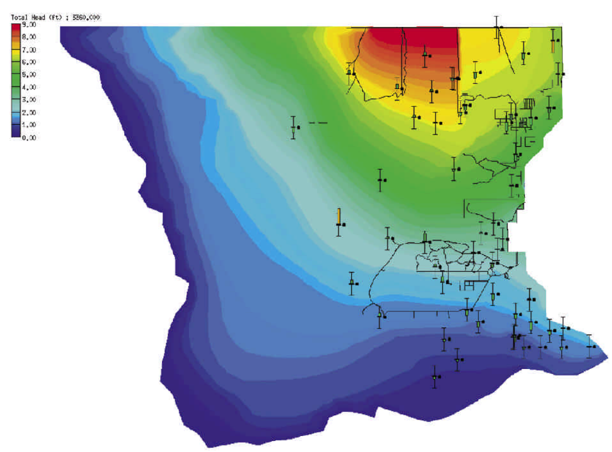
To develop a multi-dimensional surface water and groundwater modeling capability that can evaluate water delivery plans to the South Florida Ecosystem (including Everglades National Park—ENP and South Dade County).

Methodology

The developed code (FEMWATER123) uses the Galerkin finite element method to simulate one-dimensional canal flow, two-dimensional overland flow, and three-dimensional groundwater flow in a coupled manner. The canals are simulated using the one-dimensional diffusive wave assumption including hydraulic structures with individual operation rules that are updated at one minute intervals. The overland areas are simulated using the two-dimensional diffusive wave assumption while variably saturated groundwater flows are calculated using Richards equation. The FEMWATER123 code is supported by the Department of Defense (DoD) Groundwater Modeling System (GMS).

Results

The initial application of the FEMWATER123 code was to the hydrodynamically complex region of the Everglades National Park and Dade County Florida. This region encompasses flood control structures, drought-wet hydrologic cycles, multiple wells for both extraction and recharge, and a complex series of water management rules that are used to distribute water throughout the area. The parallel implementation of this code can run 1-year simulations in less than 8 hours, thus allowing for many complex water management scenarios to be tested and optimized for both flood control and environmental benefits for both surface and subsurface waters, within a reasonable time frame.



Everglades National Park, total hydraulic head (in feet), with whisker indicators showing the difference between computed head and measured head at numerous sampling wells within the Park

Significance

This dual-use HPC code makes possible a means to accurately simulate potential management scenarios within highly complex wetland environments common to DoD-managed lands and non-military lands of national interest. Coupled surface water-groundwater calculations of this type were not possible in a cost efficient and effective manner in the past.

Computer Resources: Cray T3E, IBM SP2 [ERDC MSRC] and IBM SP3 [ASC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Coupled Structured-Unstructured Flow Simulation

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Impact to DoD: *DoD scientists are using high performance computers to solve flow problems more quickly and efficiently. This provides the DoD with an efficient means of predicting the hydrodynamic effects of water-based military activities and for for lessening their destructive impact on flora, fauna, and personnel.*

Objective

To implement combinations of structured and unstructured grids in a scalable computational framework for solving free-surface flow problems that arise from environmental concerns associated with military and civilian activities.

Methodology

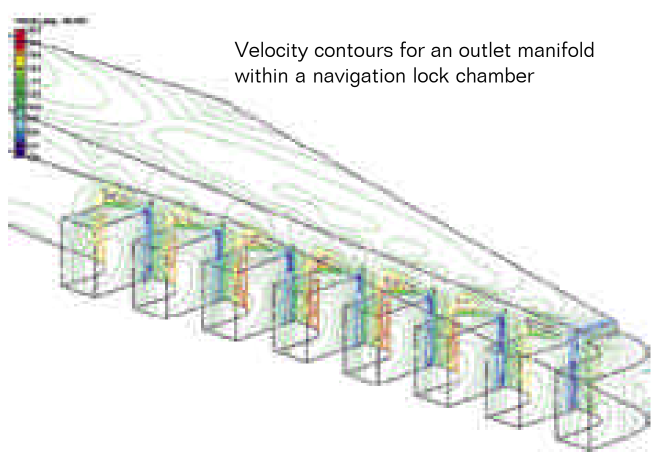
In computational physics and engineering, sequentially ordered (structured) grids facilitate rapid calculation at the expense of geometric flexibility, while non-sequential (unstructured) grids offer geomteric flexibility with lesser speed. By using these two types of grids simultaneously for different regions of the same flow problem, however, one can achieve the best of both worlds. Specifically, unstructured grids can be used selectively near irregular boundaries, with structured grids covering the rest of the computational domain. Moreover, the coupled implementation of structured and unstructured flow-simulation schemes lends itself naturally to parallel processing. This work was under CHSSI Project EQM-1.

Results

Structured and unstructured flow solvers have been successfully developed and tested in both a coupled and an uncoupled operation for scalability and similarity for several benchmark flow problems. A dynamic grid-interfacing scheme has been developed, which couples the two flow solvers in a single parallel framework. For coupled operation, unstructured components reside on one set of processors, and unstructured components occupy another, with message passing used to convey information back and forth between the two.

Significance

This effort will provide the DoD with a computationally efficient means of predicting the hydrodynamic effects of water-based military activities, and of evaluating measures for lessening their destructive impact on flora, fauna, and personnel alike. The results of this development can be used in the design of navigation infrastructure on strategic waterways and homeports, to assess the environmental impacts of said infrastructure on the aquatic movement, and to formulate engineering measures that mitigate these impacts.



Velocity contours for an outlet manifold within a navigation lock chamber

Computer Resources: IBM SP2 [ERDC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Solving Ground Water Remediation Problems

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T.L. McGehee

Texas A&M University, Kingsville, TX

Impact to DoD: *DoD scientists are using high performance computers to develop comprehensive ground water models and simulations for optimizing remediation strategies potentially saving millions of dollars in cleanup costs.*

Objective

ERDC engineers are using FEMWATER as a ground water model for large military site remediation. Donnell, Tracy, and McGehee are developing a regional scale model that can address a wide range of groundwater management questions at Defense Distribution Depot, San Joaquin, CA (DDJC-Sharpe). The developed model will be housed within the Department of Defense Groundwater Modeling System (GMS). As shown in Figure 1, this tool will assist remediation activities at DDJC-Sharpe and help to determine the ultimate fate of contaminants. Tracy, Talbot, Holland, Turnbull, Donnell, and McGehee are obtaining a parallelized version of FEMWATER that can be efficiently applied for large-scale, high-resolution subsurface modeling investigations required by the DoD. FEMWATER can model a steady state or transient analysis with either constant or variable density.

Methodology

The parallel version of FEMWATER, a three-dimensional finite element numerical model for simulating density-dependent flow and transport in variably-saturated media, was employed. The major processes that may be modeled are advection, dispersion/diffusion, adsorption, decay, biodegradation, and source/sink. Parallel FEMWATER has five parts: (1) A C program to generate all needed include files and the QSUB file. (2) A C program to partition the grid using parallel METIS (Karypis, 1999). (3) A Fortran and C program to write files containing geometry, boundary conditions, and ghost data for each processing element (PE). (4) The parallel FEMWATER program written in Fortran. (5) The post-processor program written in Fortran to combine output files generated by each pe.

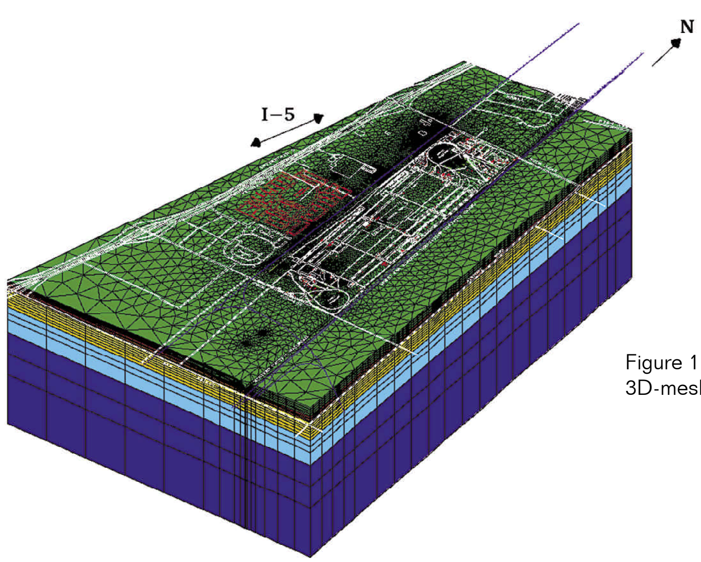

Figure 1. Oblique view of the FEMWATER 27 vertical layer 3D-mesh for DDJC-Sharpe

Results

To evaluate the impacts of proposed percolation pond locations on the existing TCE plumes, it became evident that an unsaturated vertical layer resolution of 0.50–1.50 ft was necessary in the vicinity of a test pond. The refined three-dimensional mesh with these constraints, ran the problem size up to 240,324 nodes, 461,214 elements, 8 material types, for a total 27 vertical layers and a memory size exceeding 3 gigabytes of memory. A pump and treat remediation study for a large military site was successfully completed using this code on DoD HPC resources. On the T3E scaled speedup for this problem from 8 PE's to 64 PE's was 89.6%, and parallel speedup was 5.1.

Significance

The nation has many military sites with groundwater contaminant cleanup issues (similar to that shown in Figure 2). Modeling systems are essential for the DoD to optimize remediation and provide cost efficient cleanup. Most of these sites experience highly heterogeneous subsurface environments that complicate remediation efforts. By analyzing remediation scenarios for military sites numerically, potentially millions of dollars can be saved by demonstrating the effectiveness of a given system before it is installed in the field. This in turn allows the warfighter more resources for other mission-related activities.

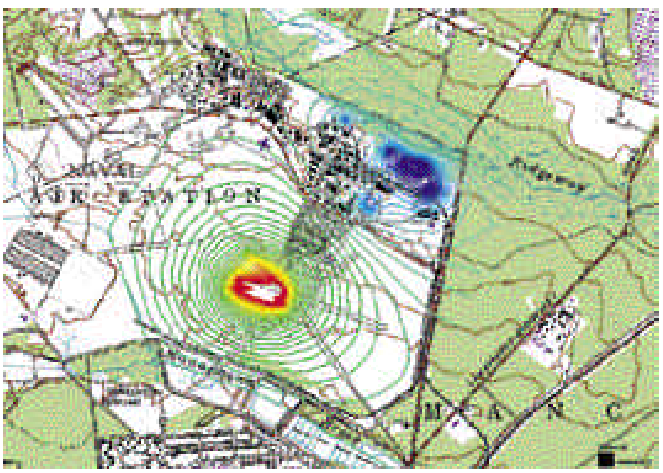

Figure 2. Groundwater contaminant contours beneath a typical DoD site

Computer Resources: Cray T3E, IBM SP, and SGI Origin 2000 [ERDC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Long-Term Simulations of Aquatic Systems

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Impact to DoD: *DoD scientists, using high performance computers, are able to examine environmental impacts without endangering aquatic environments.*

Objective

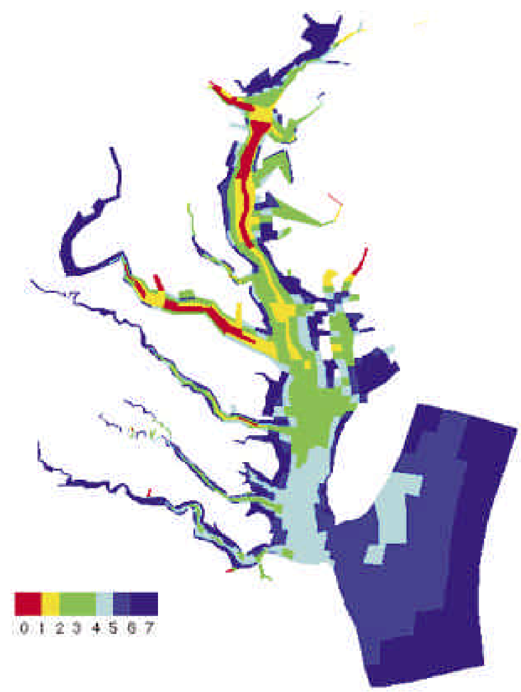
To apply models of environmental chemistry and biology to aquatic systems for long-term simulations to evaluate the environmental impacts associated with DoD mission activities. Simulations on the order of decades are required to fully evaluate the effects of DoD mission-induced alterations on the aquatic environment since these environments and their components (e.g., bottom sediments, sea grass, nutrient stores, etc.) have long response times and process memories. High performance computing is required to make such simulations feasible.

Methodology

Domain decomposition was used to enable high performance parallel computing. Two grid partitioning methods were explored, METIS and Hilbert Space Filling Curve (HSFC). The Message Passing Interface (MPI) was incorporated into model source code to provide the capability to execute multiple sub-domains on different numbers of processor elements (PEs). The codes were written to be portable among various machines and with varying numbers of PEs. This HPC approach is being used successfully to conduct three-dimensional model studies for large, valuable aquatic systems, such as military homeports. In addition, these models have high dual-use capabilities as exemplified by their use in management of aquatic ecosystems of national importance such as Chesapeake Bay and Florida Bay. These models employ a large number of state variable (e.g., 30 variables) to describe the chemistry and biology of the system and a typically executed to simulate long-term conditions (decades).

Results

Extensive testing was performed to evaluate both parallel and scaled speedup on DoD HPC resources with varying numbers of processors (from 1 to over 100 processors). Of the two partitioning methods explored, METIS usually performed better than HSFC by providing superior load balance. This HPC methodology has been used successfully and extensively to conduct the Chesapeake Bay Tributary Refinement Model Study, where 20-year simulations were required. For example, use of 32 processors for this application cut execution time from about 300 hours per 20-year simulation to less than 25 hours.



Bottom dissolved oxygen (mg/l) is plotted in plain view from a Chesapeake Bay simulation, where the red areas indicate depleted dissolved oxygen that typically occurs in the summer and early fall

Significance

With this HPC capability, DoD now can apply high-fidelity models of the aquatic environment in support of environmental management that could not be considered previously. Such models provide reliable predictions of the likely impacts of DoD activities on the aquatic environment. These predictions are then used to formulate mitigation and avoidance plans which minimize the environmental impacts of DoD activities while preserving mission-relevant requirements. Variations of this model can now be applied to assess the transport/fate of contaminants, toxic chemicals, and chemical/biological agents in the aquatic environment as well.

Computer Resources: Cray T3E, SGI Origin 2000, and IBM SP [ERDC MSRC]

CTA: EQM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Design of High Energy Density Materials

J.A. Boatz

Air Force Research Laboratory (AFRL), Edwards AFB, CA

Impact to DoD: *High performance computers are being used along with the CHSSI code GAMESS, to identify, characterize, and develop advanced high energy density compounds for use in rocket propellant applications.*

Objective

To identify, characterize, and develop advanced high energy density compounds for use in rocket propellant applications.

Methodology

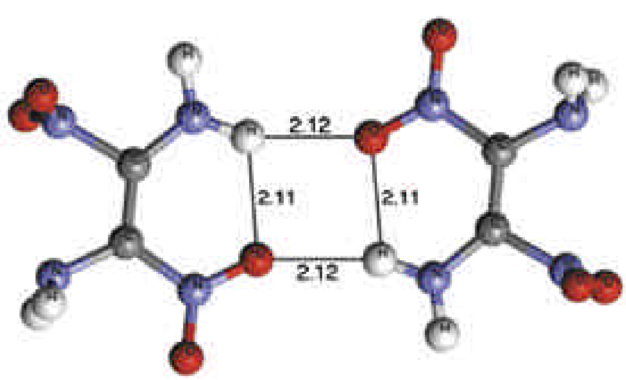
Ab initio electronic structure methods are used to accurately predict the molecular and electronic structures, spectroscopic constants, and thermochemical properties of potential high energy density compounds. Computational methods are used to screen a wide variety of high energy compounds so that the most promising candidates can be identified and targeted for experimental synthesis. The parallel capabilities of the GAMESS quantum chemistry code, which has been adapted to run on scalable platforms under the CHSSI program, have played an integral part in this project.

Results

1,2-diamino-1,2-dinitroethylene has been proposed as an advanced propellant ingredient. It has several attractive features, including an optimal chemical balance (decomposition products of CO, H2O, and N2) and the possibility of being shock-insensitive yet having high energy content. The intramolecular and intermolecular interactions of the cis and trans isomers of 1,2-diamino-1,2-dinitroethylene, which are thought to play a critical role in providing kinetic stability, have been characterized using self-consistent field and second-order perturbation theory methods. These calculations predict a network of strong hydrogen bonds which contribute to the kinetic stability of this compound.

Significance

The design of new high energy density materials for propulsion applications demands a balance between the competing factors of large energy content and shock-insensitivity. This study highlights the critical role of intra- and intermolecular interactions such as hydrogen bonding in achieving this balance.



RHF/6-311G(d,p) optimized geometry of 1,2-diamino-1,2-dinitroethylene dimer

Computer Resources: IBM SP [ASC MSRC]

CTA: CCM

JWCO: Joint Theater Missile Defense, Joint Readiness and Logistics and Sustainment of Strategic Systems

Thermal Degradation of Ceramic Interfaces

E.A. Jarvis and E.A. Carter

University of California at Los Angeles, Los Angeles, CA

Impact to DoD: *DoD researchers are using high performance computers to model Thermal Barrier Coatings (TBCs) with other alloys to see which combination provides the greatest protection in jet engines. This research will lead to higher performance jet engines with longer operating cycles between maintenance actions and more capable aircraft with lower maintenance costs.*

Objective

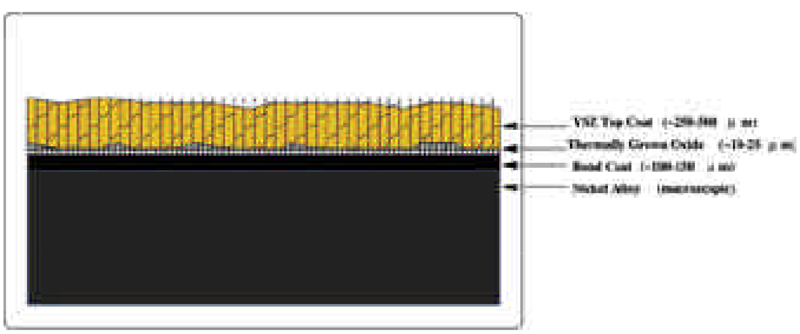
Thermal Barrier Coatings (TBCs) in aircraft engines are essential for protecting the underlying metal superalloys from thermal degradation. These TBCs consist of a thin ceramic layer with a metal alloy bond coat layer between this ceramic and the underlying engine superalloy. Unfortunately, with repeated thermal cycling, these coatings tend to crack and undergo spallation (chipping-off). The buildup of a Thermally Grown Oxide (TGO) region is thought to be a chief perpetrator of TBC failure. Another possible cause of failure, zirconia phase transitions, can increase lattice mismatch and thermal expansion strain at the metal-ceramic interface. Increased understanding of the complex interactions contributing to spallation will provide insight into the causes of failure and possible means by which to improve TBC lifetimes.

Methodology

This study employs the Generalized Gradient Approximation (GGA) within plane wave Density Functional Theory (DTF) using the Vienna Ab initio Simulation Package (VASP) and the Projector Augmented Wave (PAW) method. The VASP calculations used ultrasoft pseudopotentials to replace the core electrons. The PAW method is an all-electron electronic structure method based on DFT that consists of a plane wave "pseudo" wave function and an expansion of atomic and psuedo atomic orbitals around each atomic center.

Results

We characterize several surfaces of alumina, zirconia, and nickel (the largest percentage components of the engine superalloy) and study their interfaces. Our calculations provide atomic-level understanding for the observed increase in spallation with increasing TGO thickness. The alumina-zirconia and alumina-nickel studies provide new comprehension of weak adhesion between these interfaces and motivate our suggestion of limiting the aluminum content in the bond coat.



Schematic cross-section of a thermal barrier

Significance

In order to achieve maximum power and fuel efficiency, aircraft engines must operate at high temperatures, often above the melting temperature of the engine metal alloy. To realize this goal, a TBC must serve to protect the underlying metal alloy components. This study characterizes the materials present in TBCs and the interfaces formed between these materials at the atomic level. These results can then be linked to larger-scale experimental observations and form complementary insight into the mechanisms involved in TBC failure and possible means of improvement.

Computer Resources: IBM SP2 [MHPCC DC] and SGI Origin 2000

CTA: CCM

JWCO: Precision Fires

The Tight-Binding Method as a Predictor of Novel Materials and Properties

D.A. Papaconstantopoulos and M.J. Mehl

Naval Research Laboratory (NRL), Washington, DC

Impact to DoD: *DoD researchers are using high performance computers to develop an efficient computational method for studying materials properties which will lead to the design of new materials for DoD needs.*

Objective

The objective of this work is to provide DoD researchers an efficient computational method for the first-principles study of materials properties. Such studies include understanding materials properties and making predictions of materials with improved electronic and mechanical properties.

Methodology

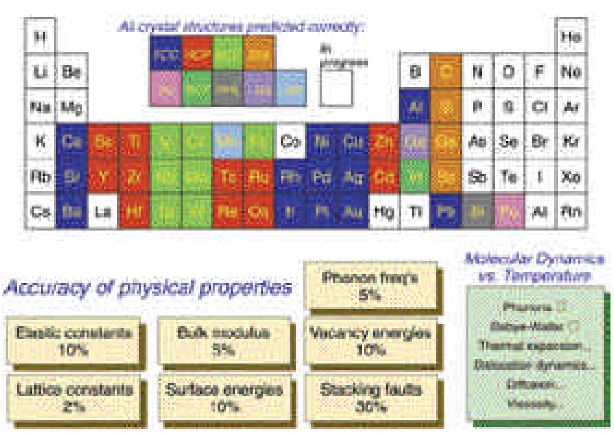
The tight-binding theory of quantum mechanics is used to bridge the gap between highly accurate but slow and memory consuming density functional theory calculations and fast but less accurate atomistic potential methods. In calculating the cohesive energy of solids, we demonstrated the same level of accuracy as the so-called "local-density" methods with three orders of magnitude improvement in computational speed. The code runs in both scalar and parallel mode. The parallel efficiency is on the order of 80%.

Results

As is shown in the figure below, we have applied this method to determine structural energy orderings, elastic constants, phonon frequencies, surface energies, stacking fault energies, and the energetics of various defects and interstitials. The method also provides electronic structure information in terms of energy bands and densities of states. The method has also been extended to include temperature dependence via molecular dynamics. Results have been obtained for 50 single elements in the periodic table. The tight-binding parameters for these elements are available for use by DoD researchers in materials science.

Significance

The immediate significance of this work is to promote basic research in materials science and solid state physics, which is expected to lead to the design of new materials for DoD needs.



The colored squares indicate those elements for which we have developed tight-binding parameters, and show the ground-state crystal structure of each element. The figure also indicates the accuracy of physical properties determined by the method. These accuracies are comparable to first-principles results. Finally, molecular dynamics capabilities are shown in the green box.

Computer Resources: IBM SP2 [ASC MSRC] and SGI Origin 2000 [ASC and ARL MSRCs]

CTA: CCM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Computational Chemistry Models of Gun Tube Erosion

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G.H. Lushington
Ohio Supercomputer Center, Columbus, OH
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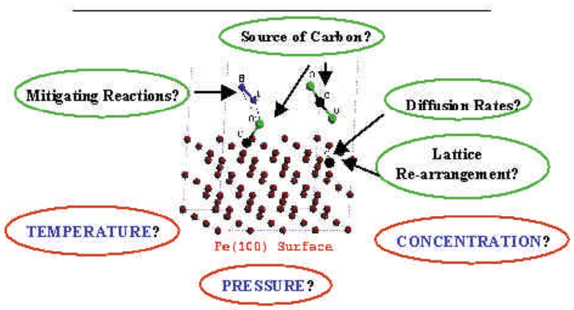
University of Pittsburgh, Pittsburgh, PA

Impact to DoD: *DoD scientists are using high performance computers and computational chemistry to model the carbon/hydrogen deposits in guns and through such insight, suggest modifications to propellants and gun tube linings to reduce or prevent gun tube erosion.*

Objective

Both carbon and hydrogen produced in the propellant combustion drastically alter the mechanical properties of the gun steel. This project is using computational chemistry to understand the carbon/hydrogen deposition process, and through such insight, suggest modifications to propellants and gun tube linings to reduce or prevent the effects of carbon and hydrogen on gun tube erosion.



Computer models of propellant combustion products interacting with iron surfaces

Methodology

Computational chemistry models using Pseudopotential Planewaves are being used to successfully model the bulk and surfaces properties of iron, including reactions taking place at the surface involving hydrogen, carbon, and oxygen.

Results

The resulting structure for the CO/Fe(100) surface interaction is in excellent agreement with available experimental data, predicting a tilt angle of 51 Degs. and a carbon distance of 0.62 Å, with experiment giving 45-55 Degs. and 0.60+/-0.1 Å, respectively. The binding energy of CO on Fe(100) is predicted to be 57 Kcal/mole, compared with an experimental result that ranges from -30 to -36 Kcal/mole, which is suspect. CO interacting with the Fe(111) surface produces an auto-dissociative product that results in the direct deposition of both carbon and oxygen into the iron matrix. An adsorption energy of -25 Kcal/mole is predicted, in excellent agreement with experimental at -20 +/- 5 Kcal/mole. Potential energy surfaces for hydrogen molecule interacting with the Fe(111) surface found that H2 also auto-dissociates and embeds itself into the iron matrix.

Significance

This collection of data offers an explanation for the persistent and consistent concentrations of carbon, oxygen, and hydrogen in gun steel, and provides a model which could be used for exploring coatings that could trap the hydrogen and reduce this source of gun tube erosion.

Computer Resources: SGI Origin 2000 [ARL MSRC]
CTA: CCM
JWCO: Precision Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

Simulation of Turbulent Combustion in a Full-Scale Combustor

S. Menon

Georgia Institute of Technology, Atlanta, GA

Impact to DoD: *DoD engineers are using high performance computers to reduce the overall development cost and time for new engines for tanks, helicopters, and aircraft.*

Objective

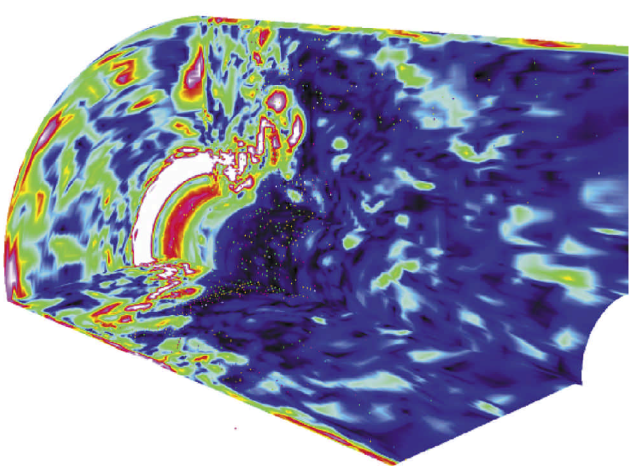
A new simulation methodology is being developed to investigate the design of liquid fuel injectors in full-scale combustors in order to optmize the combustion process. Control of the combustion process can lead to improvements in engine design by reducing fuel consumption, engine size, and weight. This in turn would result in a significantly reduced logistic burden for the next generation, rapidly deployable, and highly mobile air and ground systems. Development of a numerical capability would also reduce the overall development cost and time needed to develop new engines for tanks, helicopters, and aircraft.

Methodology

Time-accurate simulations are being performed using an optimized parallel simulation code using the technique of large-eddy simulations (LES). The simulation tool solves the conservation of mass, momentum, energy, and species using a fourth-order accurate scheme. New subgrid combustion and turbulence models are being implemented to capture the effects of small-scale turbulent mixing and molecular diffusion processes (these processes play a critical role in the combustion process and must be resolved accurately). A key advantage of this approach is that full-scale combustors can be simulated using relatively coarse grid resolution without significantly compromising accuracy.

Results

Simulation of premixed combustion and spray mixing have been carried out in a full-scale Dry Low Emission (DLE) LM-6000 General Electric gas turbine combustor. Comparison of predicted results with data showed that even with a very coarse grid (500,000 grid points), the present result was in excellent agreement with data. Analysis of spray mixing and vaporization shows that the droplets tend to accumulate in regions of low shear which occurs between regions of large coherent structures. Additional studies with heat release are underway to deterimine the impact of shear on mixing and combustion.



Swirling spray vaporization and mixing in a DLE LM-6000 gas turbine combustor. The circular plane shows the vorticity contours and the streamwise plane shows the shear regions with the locations of the droplets.

Significance

The prediction of premixed combustion in the LM-6000 was carried out using a single simulation without requiring any ad hoc adjustments of "constant". This is in contrast to current (time consuming) practice in the industry of modifying the model coefficient and carrying out repeated simulations to match data. The development of the present LES has shown the feasibility of carrying out design studies within a realistic time frame. This capability is of great interest to the engine community since it can result in a significant reduction in development cost. The present LES approach can also be used to study different design strategies to control the combustion process thereby reducing emissions and fuel consumption.

Computer Resources: Cray T3E [NAVO MSRC] and SGI Origin 2000 [SMDC DC]

CTA: CFD

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Attenuation of Shocks Through Structured Media

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Naval Research Laboratory (NRL), Washington, DC

Impact to DoD: *DoD scientists are using high performance computers to counter terrorist threats to personnel and structures.*

Objective

Numerically investigate the effect of structured media on the mitigation of the shock waves caused by accidental and planned explosions.

Methodology

The attenuation of shock waves by passage through protective shields, modeled as intersecting rods of varying cross section and blockage areas, are numerically investigated with FAST3D, a CHSSI code application. The FAST3D model is a state-of-the-art, portable, three-dimensional computational fluid dynamics tool based on Flux-Corrected Transport coupled to the Virtual Cell Embedding algorithm for simulating complex geometries. Structure geometry, porosity, and placement is parametrically studied to determine their effect on the mitigation of planar shocks and to determine ways to mitigate the adverse effects of these shock waves with minimal shielding.

Results

The simulations model the effect of a normal shock wave propagating through a single attenuator of varying cross section aligned perpendicular to the flow direction (Figure 1). As the blockage area of the attenuation device increases, the amount of shock attenuation (as measured by the shock over-pressure) increases, the speed of the transmitted shock decreases, and the arrival time of the transmitted shock increases, independent of the cross section shape. As shown in Figure 2, for a square cross-section attenuator, increasing the blockage area results in a weaker transmitted shock and a later arrival, as compared with the circular cross-section attenuator. Figure 3 represents an example of the overall flow development data generated by the model.

Significance

Recent terrorist activities have resulted in partial and total destruction of military and civilian buildings with a significant number of fatalities. These attacks have generated considerable concern over our ability to protect buildings and personnel from this ever-present threat. Recent work has begun to address these issues by considering ways to protect existing buildings and developing novel design techniques for new buildings.

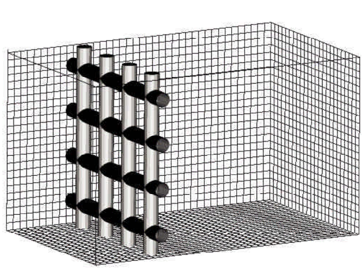


Figure 1. Schematic of the computational domain along with one of the attenuators studied

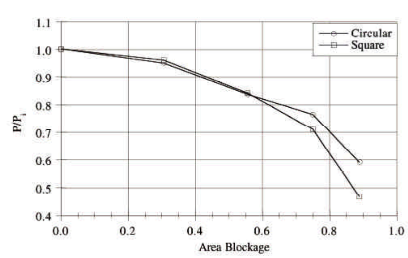


Figure 2. Summary of shock attenuation study. Data taken at the time the transmitted shock passes the plane located at x = 30 cm.

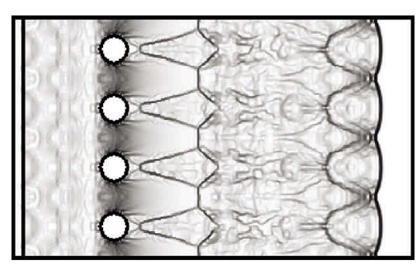


Figure 3. Computational schlieren showing overall flow development for a M = 5 incident shock (Time = 198 micro seconds)

Computer Resources: SGI Origin 2000 [NRL DC] and SGI PCA [NAVO MSRC]

CTA: CFD

JWCO: Military Operations on Urbanized Terrain, Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

Simulation Based Acquisition (SBA) of the USMC Medium Tactical Vehicle Replacement (MTVR)

D. Gunter

Tank-Automotive Research, Development and Engineering Center (TARDEC), Warren, MI

Impact to DoD: *High performance computers are being used to develop tools capable of accurately predicting vehicle performance. This allows DoD to make informed acquisition decisions in less time and reduces the risk of buying vehicles that do not meet performance requirements.*

Objective

To develop tools capable of accurately predicting dynamic vehicle performance under the limited time constraints of the SBA of the United States Marine Corps (USMC) MTVR.

Methodology

Three-dimensional, multi-body dynamic model templates of various truck designs were developed before convening of Source Selection Evaluation Board (SSEB) using LMS-CADSI's Dynamic Analysis and Design System (DADS) modeling and simulation methodology. A performance matrix of simulations suitable for identifying whether proposed vehicles meet stringent MTVR performance requirements was developed. Data was submitted throughout the source selection process by proposed vehicle developers. The data was then incorporated into the model, which was used to perform analysis in a signficantly reduced timeframe.

Results

Executing models of the contractor designs over a specified performance matrix allowed the SSEB to evaluate the capability of each vehicle's system meeting the stringent on- and off-road performance requirements laid out in the MTVR Performance Specification, before vehicle build and test. This allowed the SSEB to make informed decisions in a reduced amount time. The ground work done prior to convening the SSEB, combined with the computational speed of today's supercomputers, resulted in a capability to determine vehicle performance more rapidly.

Significance

The capabilities developed through this effort allow the DoD to use modeling and simulation to make informed acquisition decisions in less time and reduces the risk of buying vehicles that do not meet performance requirements.

Computer Resources: SGI PCA and SGI Origin 2000 [TARDEC DC]

CTA: CSM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Modeling the Chemical Interactions of Nitroaromatic Compounds With Soil

J. Leszczynski
Jackson State University, Jackson, MS

Impact to DoD: *DoD scientists are using high performance computers to model the interaction of organic compounds with the soil to help the DoD better understand the toxicological impact of organic compounds on soil.*

Objective

Nitroaromatic compounds (NACs) are widespread environmental pollutants of significant toxicological concern on DoD installations. This studies seeks to contribute to a better understanding of the interactions of NACs with soil.

Methodology

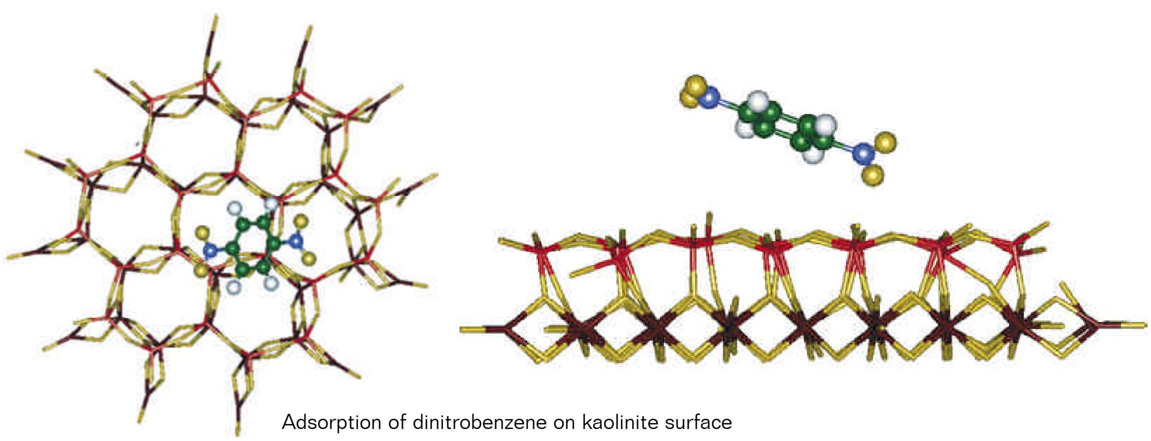
High level ab initio methods and approximtate semiempirical methods were used to study nitroaromatic compounds on clay and iron surfaces. The clay and iron surfaces were modeled at the atomic level by representing the surface as a "supermolecule" or cluster of atoms. Recently, these techniques were used on AHPCRC supercomputers to reveal details of molecular level of processes involved in NACs-soil interactions and a process of their reduction by zero-valent iron.

Results

For the clay calculations, two different size clusters were used: an 84 atom cluster with stoichiometric formula of $Al_{12}Si_6O_{42}H_{24}$ *and a 270 atom cluster with stoichiometric formula of* $Al_{36}Si_{24}O_{138}H_{72}$*. For both clusters the adsorption energies were computed.*

Significance

The clay calculations showed that the nitroaromatic compounds are adsorbed by means of full molecular contact, in complete agreement with the recent experimental data. In addition, comparing the calculated adsorption energies with the available experimental data shows that the AM1 semiempirical quantum chemical method is able to cover up to 80% of the experimental adsorption energy. S uch findings allow for efficient modeling of interactions of nitrocompounds with soil.



Adsorption of dinitrobenzene on kaolinite surface

Computer Resources: Cray T3E and IBM SP [AHPCRC DC]
CTA: EQM
JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Sensors, Electronics, and Battlespace Environment

Sensors, Radars and Tactical Envionments

- strategic and tactical surveillance
- targeting and identification of land, sea, air, and space threats
- prediction, modeling, and simulation of terrestrial, ocean, lower atmosphere, and space/upper atmosphere

Large-Scale Simulations of Tiny Ultra-Low Threshold Micro-Cavity Lasers

Capt M.J. Noble, P. Sotirelis, Lt Col J.A. Lott, and J.P. Loehr

Air Force Research Laboratory, Sensors Directorate (AFRL/SN), Aeronautical Systems Center (ASC), and Air Force Institute of Technology (AFIT), Wright-Patterson AFB, OH

Impact to DoD: *High performance computers are being used for rapid analysis, design, and optimization of micro-cavity lasers which have the potential to revoluntionize many Air Force systems.*

Objective

To develop a simulation tool that is capable of modeling the optical fields produced by ultra-low threshold micro-cavity lasers. Previously, the micro-cavity laser structures of military interest were too large to realistically simulate by numerical methods.

Methodology

A customized, innovative vector finite element model was used for finding the fundamental mode of cylindrically symmetric structures (as shown in FIgures 1 and 2). The problem reduces to a generalized complex symmetric sparse eigenvalue problem. The new solver is written in Fortran and makes use of several state-of-the-art numerical libraries. The old solver was written as a collection of Matlab "M" functions and Matlab library calls.

Results

The new solver achieved a speedup of approximately a factor of 25 over the old solver on a relatively small test problem. The new solver has the capability to simulate many of the record setting ultra-low threshold lasers. Results have been presented at several conferences and a number of papers are in the works. These simulations would not have been possible without the large shared memory capability of the SGI Origin 2000, which was typically pushed to the limit (4–6 GigaBytes per machine image).

Significance

Micro-cavity lasers have the potential to revolutionize many Air Force systems through their use as integrated optical phase shifters, optical phased arrays, massively parallel optical interconnects, etc. Due to the small size and extreme low power consumption of these devices, they are ideal for reducing costs in both air and space, while improving system performance. This simulator allows for rapid analysis, design, and optimization of ultra-low threshold micro-cavity lasers.

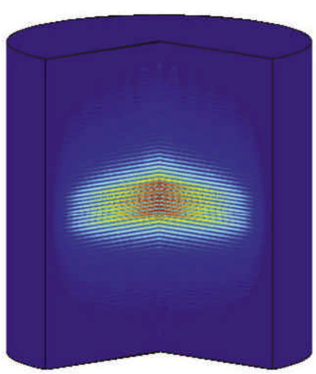


Figure 1. The lasing-mode optical-field intensity pattern, inside the laser, for a micro-cavity laser with an oxide aperture placed at the optical-intensity standing-wave null. Notice that the oxide-aperture does not provide much (radial) confinement of the optical field due to the fact it is located at the standing-wave null.

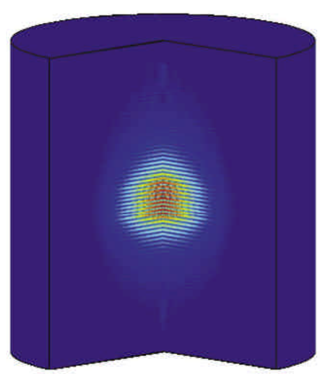


Figure 2. The lasing-mode optical-field intensity pattern, inside the laser, for a micro-cavity laser with an oxide aperture placed at the optical-intensity standing-wave peak. Notice that in this case the oxide aperture interacts with the optical field and confines it to the core of the laser.

Computer Resources: SGI Origin 2000 [ASC MSRC]

CTA: CEN

JWCO: Information Superiority, Precision Fires, Combat Identification, Joint Theater Missile Defense, Joint Readiness and Logistics and Sustainment of Strategic Systems, Electronic Warfare, Information Warfare

Scalable Sensor Modeling

M.E. Inchiosa and A.R. Bulsara

Space and Naval Warfare Systems Center (SSCSD), San Diego, CA

Impact to DoD: *DoD researchers are using high performance computers to model the design of arrays which can be used to detect underwater targets at a greater range; they may also be used in airport baggage scanners for explosives and drug detection.*

Objective

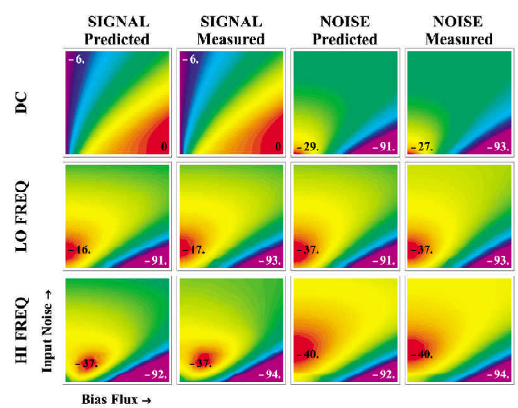
To develop scalable, portable CHSSI HPC software for modeling nonlinear sensor arrays. Using the software developed, design improved nonlinear sensors exploiting recent advances in nonlinear dynamics research.

Methodology

Nonlinear sensor arrays, subject to random and deterministic signals and noise, are modeled by systems of stochastic differential equations. Using Monte Carlo methods, the software solves such systems of equations to high accuracy. Structuring the solver to exploit coarse-grained parallelism results in highly scalable parallel performance, boasting 95% efficiency when scaled to 128 processing elements. This approach provides outstanding performance on all current parallel architectures: distributed memory, shared memory, and non-uniform memory access (NUMA). The code uses the modern features of Fortran 90/95 to achieve a modular, flexible design. Use of the industry-standard MPI library for parallelization insures cross-platform portability across the computing spectrum from Windows-based workstations to Unix-based supercomputers.

Results

Our efforts produced well-documented, standards-based, extensible software with GUI-based parameter entry and automated scientific visualization output. The developed code demonstrates high parallel scalability and portability. This software package allowed confirmation and evaluation of new modes of operating magnetic sensors based on arrays of superconducting quantum interference devices (SQUIDs). This new approach promises improved magnetometers with greater noise tolerance and sensitivity, impacting surveillance, reconnaissance, and mine detection.



The theoretically predicted results are verified by their excellent agreement with measured values from HPC-based numerical simulations

Significance

The significance of improving magnetic sensors is truly wide-ranging. Sensors based on this research may aid the warfighter by detecting underwater targets at greater range. Dual use applications include airport baggage scanners for explosives and drug detection. Switching from traditional linear sensor modalities to nonlinear dynamic ones may also reduce transducer cost and result in simpler SQUID controller electronics. This project, funded in part by Office of Naval Research 6.1 grants, promotes basic research through a better understanding of coupled nonlinear dynamic elements subject to random and deterministic forces. The software, developed with CHSSI CEN funding, allows verification of analytical approximations. The knowledge we have gained leads towards development of non-sensor applications, e.g., novel transmitter/receiver active antenna arrays. Such applications impact a wide range of warfighting capabilities such as information superiority, precision fires, combat identification, joint theater missile defense, military operations on urbanized terrain, and electronic warfare.

Computer Resources: Cray T3E [ERDC and NAVO MSRCs], SGI Origin 2000 [ASC MSRC], and HP Exemper SPP-1600 [SSCSD DC]

CTA: CEN

JWCO: Information Superiority, Precision Fires, Combat Identification, Joint Theater Missile Defense, Military Operations on Urbanized Terrain, Electronic Warfare

World Wide to Regional Mapping Engine

L. McCleary
Space and Naval Warfare Systems Center (SSCSD), San Diego, CA

***Impact to DoD:** High performance computers are being used to store large image databases which are used to display maps more quickly and efficiently.*

Objective

To develop a software mapping engine which can be used to display maps ranging in scale from world wide to highly detailed regional areas. The data input must include all Vector Product Format (VPF) data from the National Imagery and Mapping Agency (NIMA). The software must be able to produce maps in multiple projections at any desired center point and must be able to correctly handle regions which encompass the date line and/or poles. Additionally, the software must provide a basic set of overlay items and provide a means for users to geospatially register overlay symbology.

Methodology

In order to satisfy the research objectives, uniquely sophisticated algorithms have been developed. The resulting implementation has been developed in highly portable American National Standards Institute (ANSI) C which can be ported to a variety of Unix platforms, as well as Windows. Extensive testing must be performed on newly emerging VPF data. The capability needs to be accessible either as an embeddable system or in a client server mode.

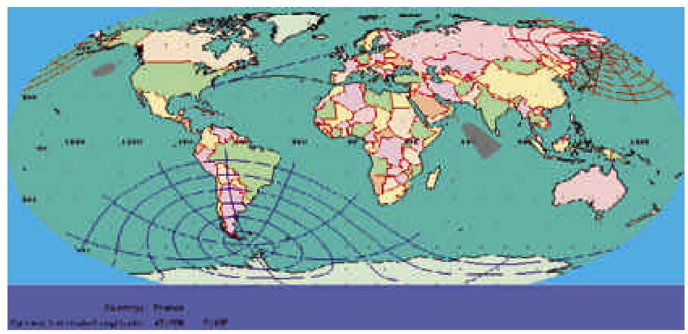


Figure 1. World view using Robinson Projection with overlay objects

Results

The actual software package is known as the Caricature Map Draw Module (MDM) which has been structured as a Graphics User Interface independent library package. Extensive testing has proven that the algorithms are extremely robust in producing world wide maps (Figure 1), including detailed areas at any region of the earth (Figure 2). Twenty one projections have been implemented to provide for a diversity of user applications. Overlay objects include great circle lines, rhumb lines, range rings, and satellite footprints. Implementation and testing has been performed on Sun, HP and SGI machines, as well as Windows NT and Windows 98. In addition, a Java client has been developed which can communicate with the server to retrieve and display MDM maps.

Significance

As a government owned system this software has proven to be extremely reliable and flexible in meeting the requirements of numerous DoD applications for organizations within the Navy, Army, Marines, Joint Staff, and the National Reconnaissance Office.

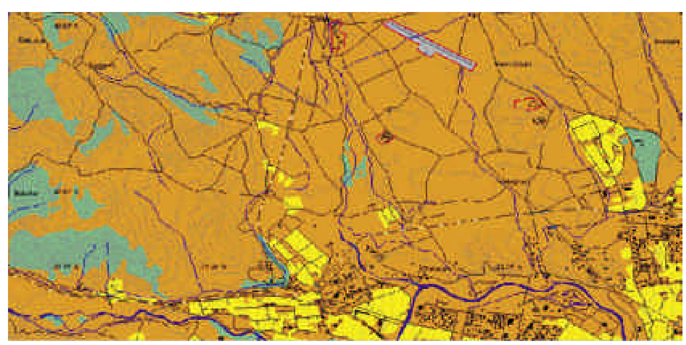


Figure 2. Detailed view using VPF level 2 data

Computer Resources: HP V2500 [SSCSD DC]
CTA: FMS
JWCO: Information Superiority, Military Operations on Urbanized Terrain, Electronic Warfare

First 1/32DEG Global Ocean Model

A.J. Wallcraft, H.E. Hurlburt, R.C. Rhodes, and J.F. Shriver

Naval Research Laboratory (NRL), Stennis Space Center, MS

Impact to DoD: *A revolutionary, "first of its kind" ocean prediction system has been developed using high performance computers that will allow the Navy to enhance anti-submarine warfare and surveillance, tactical planning, optimum track ship routing, and search and rescue missions.*

Objective

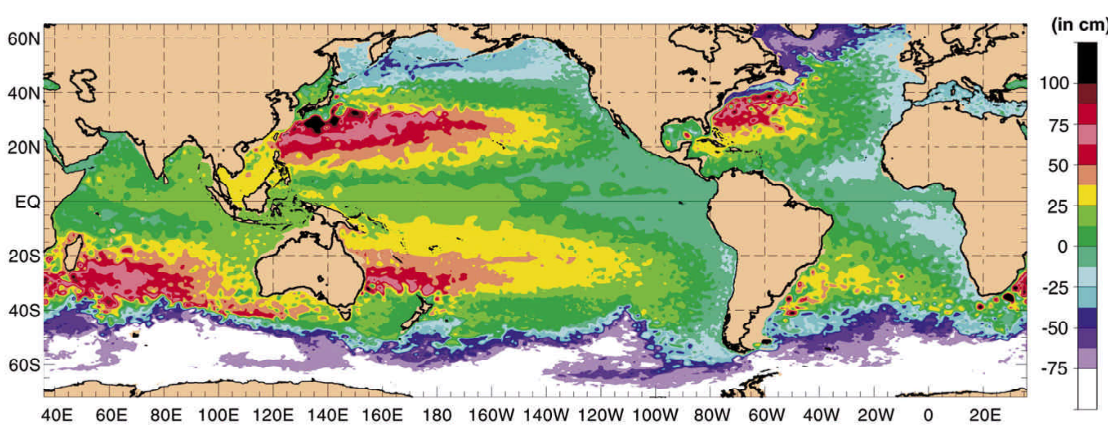
The development of an ocean prediction system that will revolutionize the Navy's ability to nowcast and forecast the ocean circulation anywhere in the world. The overall goal is a data assimilative 1/32DEG (3.5 km resolution) global ocean nowcast/forecast system for transition to Fleet Numerical Meteorology and Oceanography Center (FNMOC) by the year 2005. This includes participation in the multinational Global Ocean Data Assimilation Experiment (GODAE) set for 2003–2005.

Methodology

A scalable, portable version of the NRL Layered Ocean Model (NLOM) has been developed under the Common High Performance Software Support Initiative (CHSSI). The NLOM runs efficiently and interchangeably on computing platforms ranging from workstations to all scalable computers (Cray T3E, IBM SP, SGI Origin 2000, and HP/Convex SPP2000) currently available at the DoD HPC Major Shared Resource Centers and Distributed Centers. NLOM has a factor of 10s to 100s advantage in computer time requirements over other global and basin-scale ocean models. Even so, 1/32DEG near-global NLOM is at the very edge of computational feasibility on existing HPC systems. DoD HPC resources and DoD Challenge grants of computer time are critical for the development of this system.

Results

NLOM was first run at 1/16DEG globally in 1997 under DoD HPC Challenge. Starting from a 1/16DEG state, the first extension to 1/32DEG was run in December 1998 on a 1,488 processor Cray T3E at Cray Research. In addition to producing a three model year simulation, access to this large machine allowed us to demonstrate the excellent scalability of NLOM on the T3E. Our measured speedup for a practical run with all the usual I/O was 1.81x between 384 and 768 nodes and 1.58x between 576 and 1,152 nodes. This first simulation was extended an additional four model years on 216 and 432 T3E nodes under DoD Challenge at NAVO.



Sea surface height (SSH) snapshot from the 1/32DEG Global version of the NRL Layered Ocean Model currently running as part of an FY98–00 DoD HPC Challenge project. SSH is observed by satellite altimetry, the most important oceanic data type for operational global ocean prediction. SSH depicts current systems by narrow ribbons of color, eddies as small features marked by concentric rings of color and gyres as basin-wide features marked by closed color contours. SSH is also an integral measure of subsurface temperature/salinity structure.

Significance

It typically takes five years from the "first of its kind" ocean simulation at a given resolution to develop a nowcast/forecast system robust enough for transition to operational use. This assumes that computer system performance, and available computer resources, follow historical trends so that what was initially only possible under DoD Challenge becomes routine. By running at 1/32DEG in FY99, we are ahead of schedule for a 2005 transition. Applications for the models and the nowcast/forecast systems include assimilation and synthesis of global satellite surface data; ocean prediction; optimum track ship routing; search and rescue; anti-submarine warfare and surveillance; tactical planning; high resolution boundary conditions that are essential for even higher resolution coastal models; inputs to ice, atmospheric and bio-physical models and shipboard environmental products; environmental simulation and synthetic environments; observing system simulations; ocean research; pollution and tracer tracking; and inputs to water quality assessment. Assimilation of satellite altimeter data into the models will make more effective use of real-time altimeter data from the Navy's Geosat Follow On (GFO) mission, TOPEX/POSEIDON and ERS-2 via NAVO's Altimeter Data Fusion Center (ADFC).

Computer Resources: Cray T3E [NAVO MSRC]

CTA: CWO

JWCO: Information Superiority, Joint Readiness and Logistics and Sustainment of Strategic Systems

Data Distribution Environment for Signal Processing Applications on Parallel Architectures

P.P. Partow and D.M. Cottel

Space and Naval Warfare Systems Center (SSCSD), San Diego, CA

Impact to DoD: *Through the CHSSI, the DoD is reengineering signal processing applications that will work on a variety of platforms addressing real-world needs.*

Objective

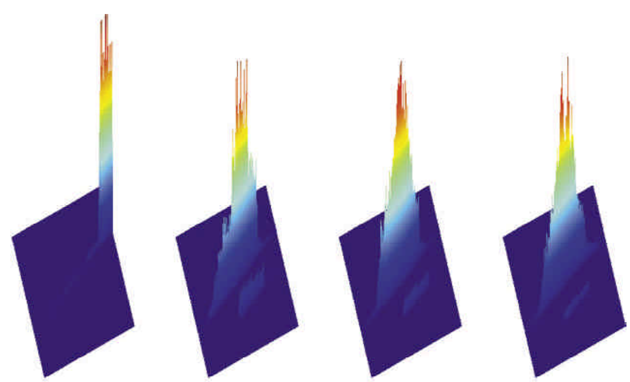
To develop a portable version of the SSC San Diego Scalable Programming Environment (SPE) and to provide versions for various HPC systems and networks of workstations. DoD embedded signal processing applications are currently developed as conventional sequential programs and then rewritten as parallel programs for a specific embedded architecture. The SPE provides a way to develop scalable, parallel signal and image processing applications that can, by simple recompilation, be ported to various HPC architectures and ultimately to embedded systems.

Methodology

The SPE is intended to be used for real-time signal processing and has been implemented as an efficient environment for building applications in a modular, flexible, scalable manner. It handles the myriad complicated details of scalable parallelism so programmers can concentrate on signal processing issues. The SPE has been successful not only in providing transparent scalability for users, but also in encouraging good software engineering practices such as modularity, well defined interfaces, and rapid prototyping of parallel programs.

Results

Under CHSSI, with very little change to the user-visible programming interface, the SPE was redesigned and reimplemented to use MPI-1 for communication between processes. Also, several DoD projects have developed SPE-based scalable, parallel modules. These include Synthetic Aperture Radar (SAR) at SSC San Diego (funded by CHSSI) and NAVAIR Patuxent River (funded by PET), Automatic Target Recognition (ATR) at Army Research Laboratory Aberdeen, and Active Acoustic Sonar Processing at SSC San Diego.



Sonar receiver response for successive transmissions using an autofocus technique on a towed line array. The algorithm adapted for platform dynamics and acoustic propagation providing improved sonar track estimation over conventional navigation instrumentation.

Significance

SPE shows that high performance, parallel programs can be made scalable and portable without a significant loss in performance. Because of the SPE's support for modular programming, the various modules can be freely interconnected in much the same style as Khoros. SPE is currently being used on several underwater acoustic-processing projects.

Computer Resources: HP V2500 [SSCSD DC]

CTA: SIP

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

High Performance Computing for C3I CEM Applications

D.M. Leskiw

Air Force Research Laboratory (AFRL), Rome, NY

Impact to DoD: *DoD scientists are using high performance computers to develop and apply parallel processing techniques to electromagnetic software to reduce the time required by production runs from days to hours.*

Objective

To develop and apply parallel processing techniques to a large-scale, legacy software system for performing electromagnetic compatibility analysis of complex systems. The software system GEMACS (General Electromagnetic Model for the Analysis of Complex Systems) is a production code developed by the Rome Research Site of the Air Force Research Laboratory and used by Air Force, Army, and Navy analysts and their contractors. The goal was to reduce the time required by production runs, which could normally take days on a single processor to hours on a multi-processor such as the Paragon.

Methodology

The GEMACS system employs low frequency, high frequency, and a hybrid of both to model and analyze the field interactions among antennas and their surrounding structures, such as an airframe (Figures 1 and 2). For the low frequency regime, the computation of the interaction and Green's function matrices were distributed while a parallel ray-tracing algorithm was used for the high frequency case—with the hybrid situation employing both techniques. The modifications to the code were made such that only the structure of the calculation was affected (parallelized), not the underlying physics. Standard libraries such as MPI were used to maximize portability.

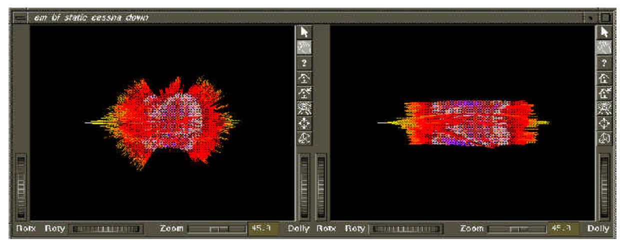


Figure 1. Two coordinate frames for visualizing the computed fields: spherical coordinates and cylindrical coordinates with azimuth plotted versus elevation. In both cases, the angle definitions are the standard ones, with respect to the aircraft body (nose forward being 0 AZ and 0 EL, azimuth is the plane of the wings, nose up is positive elevation).

Results

The system can run on networks of PCs or workstations and massively parallel supercomputers, such as the Paragon. The parallelization of GEMACS has significantly reduced the computer run-time from days to hours, while maintaining the accuracy of the original code.

Figure 2. A view in cylindrical coordinates (azimuth and elevation angles) of the scattered field and a slice at a particular value of elevation angle for all azimuth (0-360)

Significance

The Air Force and the other Services use general purpose electromagnetic simulations to analyze complex systems like reducing interference among radiating and passive electronic components mounted on airborne surveillance aircraft like the Global Hawk. The modified GEMACS code can now solve larger, more complex problems and handle higher orders of interactions.

Computer Resources: Intel Paragon [AFRL/IF and SSCSD DCs]

CTA: SIP

JWCO: Electronic Warfare, Information Superiority

Flow Response to Large-Scale Topography: The Greenland Tip Jet

J.D. Doyle

Naval Research Laboratory (NRL), Monterey, CA

***Impact to DoD:** DoD scientists are using high performance computers to model the dynamics of ocean flow with special emphasis on the effects that the low-level jet streams, caused by the mountains, have on the ocean. This study will allow the Navy and commercial shipping industries to better understand the significant hazards these phenomena pose.*

Objective

To explore the dynamical aspects of flow past large-scale elliptical topographic obstacles with special emphasis on the formation of lower-boundary jet streams emanating from the vertex of an orographic ellipsoid or "tip".

Methodology

The numerical simulations of idealized and observed flows for this study were prepared with the atmospheric portion of the NRL's Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) (Figures 1 and 2). The model is a finite-difference approximation to the fully compressible, nonhydrostatic equations that govern atmospheric motions. Idealized and real-data numerical model simulations with horizontal grid increments of 15 km were used to investigate the dynamics of low-level jet streams that form in stratified flow downstream of the vertex of large elliptical barriers such as the southern tip of Greenland, referred to as "tip jets".

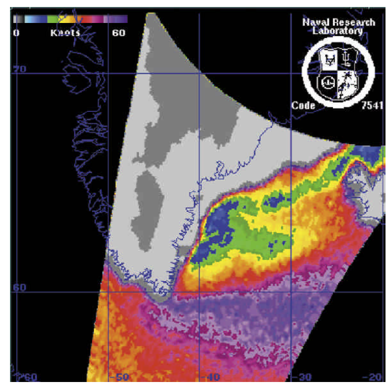


Figure 1. Near surface wind speed (knots) for ~1200 UTC 18 February 1997 derived from a satellite based SSM/I

Results

The tip jet dynamics are governed by conservation of Bernoulli function as parcels accelerate down the pressure gradient during orographic descent. In some circumstances, the Greenland tip jet is influenced by baroclinic effects such as differential horizontal (cross-stream) thermal advection and/or vertical shear. The normalized tip-jet maximum is most sensitive to changes in the basic state dimensionless mountain height and Rossby number, underscoring the importance of modulating the orographic deflections of airstreams and the Lagrangian accelerations on the slope.

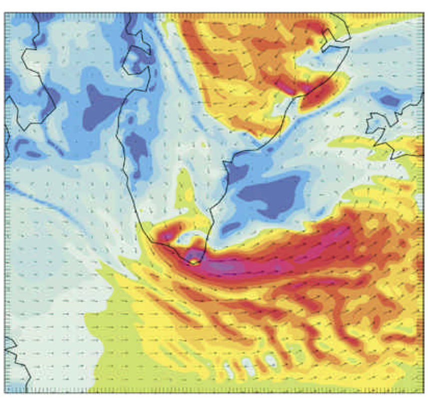


Figure 2. Near surface wind speed (knots) for ~1200 UTC 18 February 1997 derived from a COAMPS 24-h simulation fields.

Significance

This study represents the first known documentation and high-resolution simulation of orographically forced tip jets. Enhanced surface-based forcing of the ocean circulation occurs in the region of the tip jet core through large air-sea energy exchange (upward surface-heat fluxes > 800 W m-2), and at the tip jet flank through localized extrema of the curl of the surface stress. These lower-boundary jets are clearly linked to the large-scale topography and represent a significant hazard to Navy operations, commercial shipping industries, and scientific field studies in this area.

Computer Resources: Cray T90 [ARL and NAVO MSRCs]

CTA: CWO

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Synthetic Aperture Radar Image Formation (SARIF)

C. Yerkes and J.M. Weber

Space and Naval Warfare Systems Center (SSCSD), San Diego, CA

***Impact to DoD:** DoD is advancing its imaging capabilities for improved surveillance systems that will expand foliage and ground penetration research.*

Objective

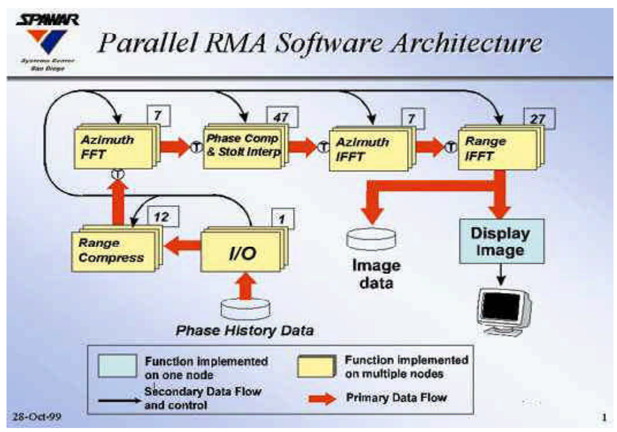
Three main objectives were set for the CHSSI SARIF project. The first was to develop scalable software for Synthetic Aperture Radar (SAR) image formation for DoD surveillance systems using advanced parallel, multidimensional spectral analysis and interpolation techniques. The second was to develop software that was portable across a range of HPC platforms. The third objective was to demonstrate the effectiveness of modular software techniques in facilitating algorithm enhancements.

Methodology

Three tasks were planned to achieve the CHSSI project goals. A Range Migration Algorithm (RMA) was developed to process ultra-high frrequency (UHF)/very high frequeny (VHF) SAR data from sensors currently being used for DoD funded foliage and ground penetration research. The process used data from the UHF SAR system operated by SRI International and from the Navy P3 UHF Ultra-Wideband SAR. The second task was the porting and parallelization of a Polar Format Algorithm, developed by ERIM Inc., to various HPC platforms. The Polar Format algorithm processes X-Band SAR data from the ERIM and Air Force Wright Laboratory Data Collection System SAR. The third task was the development of a middleware software, known as Scalable Programming Environment (SPE), to provide for the parallelism, portability, and modularity of the SAR software.

Results

The CHSSI RMA and Polar Format Algorithm were ported to multiple HPC platforms which include SGI Origin 2000, IBM SP2, Intel Paragon, HP V2500, and Windows NT. Demonstrations on all platforms were able to show significant scalability of the algorithms. The SPE middleware portion of the software was shown to be reusable in other SAR ATR and non-SAR applications. Also, the SAR algorithms were successfully ported to a CSPI embedded computer.



The SAR Range Migration Algorithm functional and data flow diagram implemented as a parallel, scalable high performance program. T he RMA is portable to multiple HPC platforms and runs on an arbitrary number of nodes selectable by the user.

Significance

Traditionally, the SAR processors that have been written for general purpose computers are sequential and take several hours to process the raw data or are only able to process a small portion of the overall data. SAR processors that have been developed for real-time hardware are inflexible and make algorithm enhancement difficult. In contrast, the CHSSI SARIF processors, which have been written for the high performance computers and have been parallelized to take advantage of the scalable software, can produce results in sub-real-time and provide the flexibility to evaluate algorithm enhancements.

Computer Resources: Intel Paragon, HP V2500 [SSCSD DC] and SGI Origin 2000, IBM SP2 [ASC MSRC]

CTA: SIP

JWCO: Information Superiority, Combat Identification, Joint Readiness and Logistics and Sustainment of Strategic Systems

Operational Wave Forecasting in Scalable Environments

R. Jensen and L. Turcotte
Engineer Research and Development Center (ERDC), Vicksburg, MS
M. Brooking and J. Dykes
Warfighting Support Center, Naval Oceanographic Office (NAVO), Stennis Space Center, MS
M. Fahey
Computer Science Corporation, Vicksburg, MS

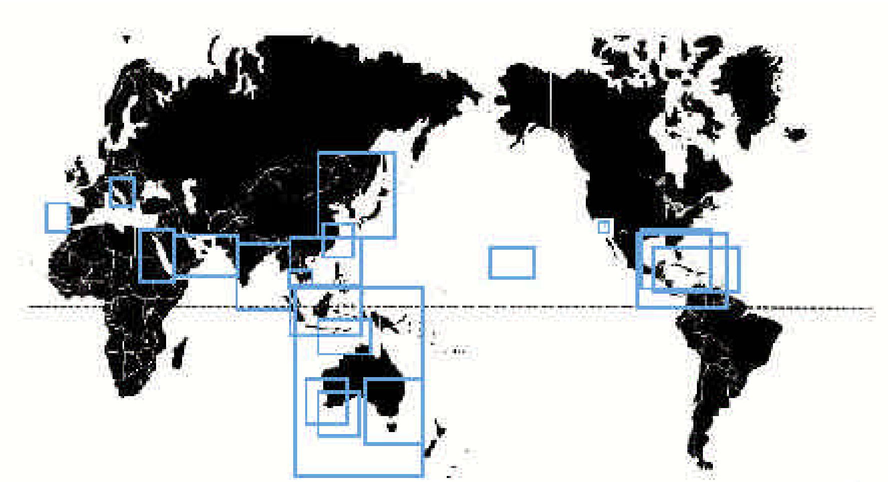
***Impact to DoD:** High performance computers are being used to develop a state-of-the-art wave modeling technology which can provide timely forecasts to military operations.*

Objective

To develop, test, and implement state-of-the-art spectrally based wave modeling technologies for Naval operational forecasts throughout the world for the simulation of deep, intermediate, and nearshore wave conditions.

Methodology

Operational wave forecasts have been performed on a routine basis by the Navy for over 30 years. The resulting information has been used for ship routing, and for operational and training exercises involving insertion of troops and equipment in the littoral zone. Accurate wave estimates for these operations are critical to the functional success, and timely transmittal of forecast information is paramount. However, there must be a balance between the sophistication in wave model physics, as well as spatial and temporal resolutions describing the processes and the timely transmittal of the estimates. Furthermore, there are constraints on the computational window at the operational forecasting centers, such that implementation of new forecast domains becomes an inverse problem. One has to select the most applicable domain size, spatial, temporal resolutions, and sophistication in the wave modeling technologies that can be successfully run within this fixed time domain. Improved wave estimates can be realized, with (1) finer grid resolutions depicting geographical boundaries, bathymetry, and the land/water interface, (2) improvements to the model physics, and (3) use of data assimilation methodologies. Implementation of any one or a combination of these viable solutions can only be accomplished by the creation of a time-buffer in the fixed forecast computational window. As part of the CHSSI in Climate/Weather/Ocean, the operational wave forecast model WAM (figure below), using parallelization methods, has successfully generated a time buffer. This was developed from a joint Army, Navy collaborative effort on existing HPC MSRC's scalable platforms.



WAM operational forecast domains (blue boxes) run at NAVOCEANO's WSC

Results

The use of parallelization tools in WAM (e.g., Fortran accelerators, OpenMP, and MPI), results from initial testing and implementation by the NAVOCEANO's Warfighting Support Center, scaled speed up values of between 2 to 10, have become a reality. The impact of this improvement in an operational forecasting arena is that finer grid resolutions can become a viable alternative for improving the wave estimates. As research activities in wave modeling continue, improved model physics can be incorporated with loss of throughput to meet overall Navy requirements.

Significance

The accuracy in operational wave forecast results, in the nearshore domain, drive the success of logistics-over-the-shore operations. The scalable version of WAM, developed under CHSSI, is running operationally at NAVOCEANO, with through-put of over 1000 individual wave forecasts performed on a weekly basis. Because of the increased efficiency, improvements to the results now can be realized.

Computer Resources: SGI Origin 2000 [ERDC and NAVO MSRCs] and Cray SV-1 [NAVO MSRC]

CTA: CWO

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

RCS and ISAR Image Predictions for Combat Ground Vehicles

R.J. Chase and H.B. Wallace
Army Research Laboratory (ARL), Adelphi, MD

***Impact to DoD:** High performance computers are being used to reduce the exposure and detectability of U.S. and friendly forces, and ground combat vehicles.*

Objective

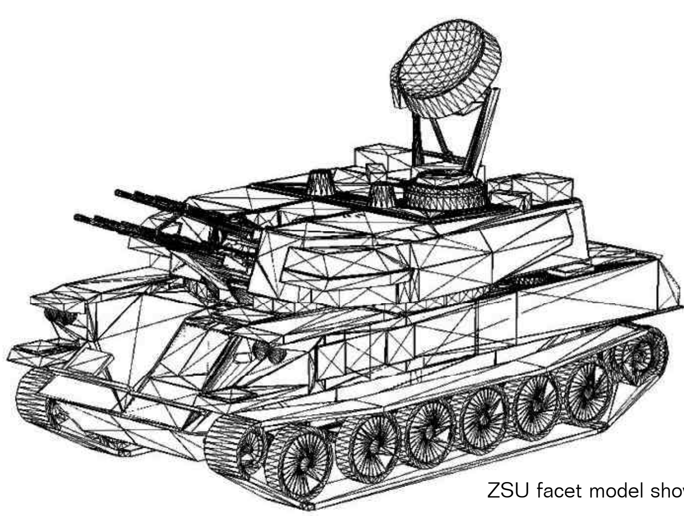
To compute the Radar Cross Section (RCS) and Inverse Synthetic Aperture Radar (ISAR) images for the ZSU-23-4 at X-band and Ka-band, and compare with ARL radar measurements and to extend the computations to W-band, the highest operational frequency range of the ARL radar.

Methodology

This work applied the DoD radar predictive software Xpatch and a model of a full-size combat ground vehicle (the ZSU-23-4, a foreign asset) to investigate and quantify the Xpatch code performance in frequency ranges well in excess of typical applications. The computer-generated results are compared with radar measurements on the ZSU taken at the ARL outdoor signature research facility. One long term goal is to generate predictive data at W-band, the highest operational frequency range of the ARL radar. A self-imposed requirement on the predictive data was to use the same parameters that were chosen for the measurement data. One complete configuration involved the ZSU situated over a metal ground plane with data taken at one elevation angle, a full 360 azimuth sweep in 0.015 steps, 256 frequencies about the center frequency, and 4 polarization states. The ZSU model for this configuration consisted of a flat, triangular, all-metal facet representation of the ZSU exterior structure, containing nearly 78,000 facets (see figure). To run this configuration, Xpatch was installed on all the Army SGI Origin 2000 machines at the ARL MSRC, and the problem was divided into 24,000 single processor jobs running in parallel under the control of a UNIX script file. This configuration consumed nearly 86,000 hours of computer time and took nearly 3-½ months of calendar time. The frequency for this configuration was in Ka-band, about a factor of 3 below the W-band goal.

Results

Data analysis involved converting the Xpatch data into the data format of the software used by the radar measurement system thus providing for a direct one-to-one comparison between measured and computed results. Comparisons between the measured and computed data showed very good results only for special



ZSU facet model shown at 12° depression angle and 45° azimuth angle *conditions. However, the discrepancies revealed areas of the model that must be modified (better ground parameters, higher-resolution ZSU model) before the frequency is pushed to higher ranges. This type of computer modeling is used to support automatic target recognition (ATR) programs and to develop predictions of radar "signatures" of vehicles.*

Significance

The strongest impact on the warfighter results from applying this predictive technology to reduce the exposure and detectability of U.S. and friendly forces. An added benefit accrues from using the technology to optimize performance and trade-off competing requirements in the design of new combat systems. This is now occurring for one of the Army's new combat systems, where application of the above software is helping to meet vehicle nonballistic survivability requirements and reduce development and life cycle costs through smart design. An immediate application from the work completed to date is to provide the model and data to the Electromagnetic Code Consortium (EMCC) for inclusion in their national repository of examples, where they will be used as a baseline for the evaluation of new or improved codes.

Computer Resources: SGI Origin 2000
CTA: CEA
JWCO: Precision Fires, Combat Identification

A Feasibility Demonstration of Ocean Model Eddy-Resolving Nowcast/Forecast Skill Using Satellite Altimetry

H.E. Hurlburt, R.C. Rhodes, C.N. Barron, and E.J. Metzger

Naval Research Laboratory (NRL), Stennis Space Center, MS

O.M. Smedstad and J.F. Cayula

Planning Systems, Inc., Stennis Space Center, MS

***Impact to DoD:** Successful demonstration of the feasibility of a truly eddy-resolving global ocean prediction system will lead to enhanced naval nowcasting/forecasting capabilities.*

Objective

To establish a fully eddy-resolving, data assimilative global ocean prediction system with at least 1/16DEG resolution.

Methodology

The NRL Layered Ocean Model (NLOM) is typically tens to hundreds of times more efficient than other ocean models in computer time/model year. This is primarily because Lagrangian layers are used in the vertical and a semi-implicit time scheme makes the time steps independent of all gravity waves. NLOM is a scalable, portable computer code that can run on any HPC system. The data assimilation was performed using a combination of optimum interpolation, subsurface statistical inference, and nudging.

Results

A 1/16DEG Pacific Ocean model north of 20DEG S was used to assimilate satellite altimeter data and then to perform month-long forecasts initialized from the data assimilative states (Figure 1). The results constitute a feasibility demonstration of ocean model eddy-resolving nowcast/forecast skill using satellite altimeter data. In particular they demonstrate (1) that satellite altimetry is a suitable observing system for mesoscale oceanic features, (2) that an ocean model with high enough resolution can be a skillful dynamical interpolator for satellite altimeter data in depicting mesoscale oceanic variability, and (3) that the high resolution ocean model can provide skillful forecasts of mesoscale variability for at least a month, when model assimilation of the altimeter data is used to define the initial state.

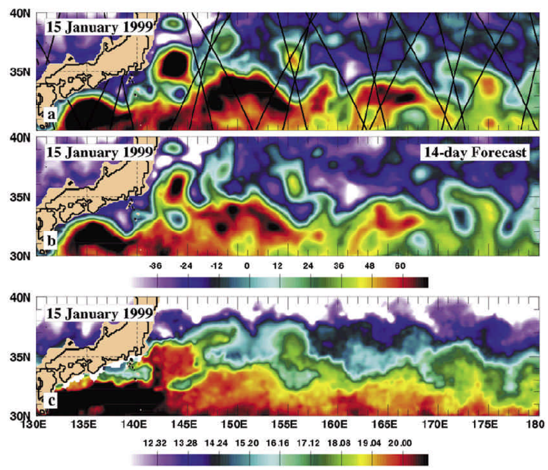


Figure1. Kuroshio region sea surface height (SSH) snapshot for 15 January 1999 from the NRL 1/16DEG Pacific model with assimilation of Topex/Poseidon and ERS-2 altimeter data. Corresponding SSH snapshot from a 14-day forecast initialized on 1 January 1999. 1/8DEG sea surface temperature (SST) analysis from satellite IR imagery.

Significance

The 1/16DEG Pacific NLOM feasibility demonstration of ocean model eddy-resolving nowcast/forecast skill is a critical milestone in the development of a truly eddy-resolving global ocean prediction system for the U.S. Navy. Earlier there was doubt that satellite altimeter data was a sufficient observing system for mapping the evolution of oceanic mesoscale features such as eddies and the meandering of oceanic currents and fronts. This work demonstrates that satellite altimetry is sufficient for that purpose.

Computer Resources: Cray T3E [ERDC and NAVO MSRCs]

CTA: CWO

JWCO: Information Superiority, Joint Readiness and Logistics and Sustainment of Strategic Systems

Accurate Schemes for Wave Propagation and Scattering

M.R. Visbal and D.V. Gaitonde

Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

Impact to DoD: *DoD scientists are addressing target identification, radar, and sonic signature predictions by using high performance computers to perform high-fidelity wave propagation simulations.*

Objective

Wave propagation plays a critical role in the design and performance of many weapon systems. Examples of acoustic and electromagnetic wave effects include jet screech and radar scattering. Analysis of such complex phenomena is facilitated by large-scale, high-fidelity numerical simulations. Towards this end, this project develops highly accurate and efficient solvers for the simulation of broad-band acoustic and electromagnetic wave phenomena in time domain.

Methodology

The pertinent wave physics is described by the Euler or linearized Euler equations for acoustics and the Maxwell equations for electromagnetics. These are expressed in a general curvilinear coordinate frame in order to accomodate complex configurations. Each system of equations is solved employing a highly accurate, 6th-order compact scheme which exhibits minimum energy dispersion and dissipation. A novel 10th-order low-pass filtering approach is also incorporated in order to eliminate parasitic numerical phenomena associated with grid imperfections, multi-domain interfaces and approximate boundary conditions.

Results

The high-order methodology was applied successfully to a variety of benchmark aeroacoustic simulations. Figure 1 shows the scattering of a cylindrical fuselage section of the sound generated by a periodic compact source. The sound directivity predicted by the new approach was found to be far superior to conventional methods. The filtering procedure was also instrumental in the development of a new radiation farfield treatment based on the decay of acoustic energy at coarse-fine grid interfaces (Figure 2).

Figure 1

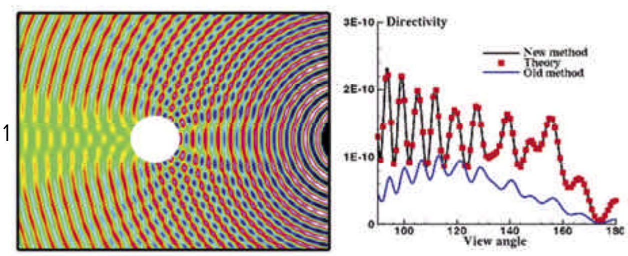


Figure 2

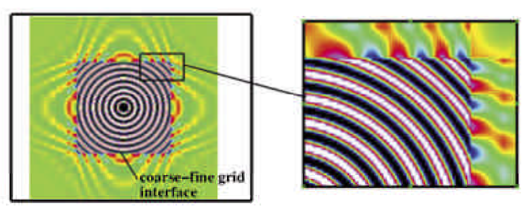


Figure 1. Acoustic scattering off a cylindrical fuselage
Figure 2. A new farfield radiation treatment applied to an acoustic source

Significance

This work addresses requirements of electromagnetics and acoustics computations for target identification, radar and sonic signature predictions. The physics of electromagnetic or acoustic phenomenon is based on diffraction and refraction from a transmitter to scatterers, which involves unavoidably long-range wave propagation. In the high-frequency regime, conventional algorithms incur large numerical errors leading to unacceptable wave distortion. The new schemes developed demonstrate the potential to overcome the above limitations and will greatly enhance the warfighting technology.

Computer Resources: Cray T90 [ERDC and NAVO MSRCs] and IBM SP2 [ASC MSRC]

CTA: CEA

JWCO: Precision Fires, Combat Identification

Weapons

Armament and Electronic Warfare Technologies

Conventional Weapons

guns, mines, bombs, and torpedos
launching systems
countermine systems
explosive ordnance disposal
guided missiles

Directed-Energy and Electronic Warfare

electromagnetic energy
atomic and subatomic particles
maximizing the operational use of EM weapons

Radar Signature Predictions with the Highly Scalable, Higher Order SWITCH Code

S.S. Bindiganavale, Y.C. Ma, G.E. Antilla, and M.I. Sancer

Northrop Grumman Corporation, Pico Rivera, CA

K.C. Hill

Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

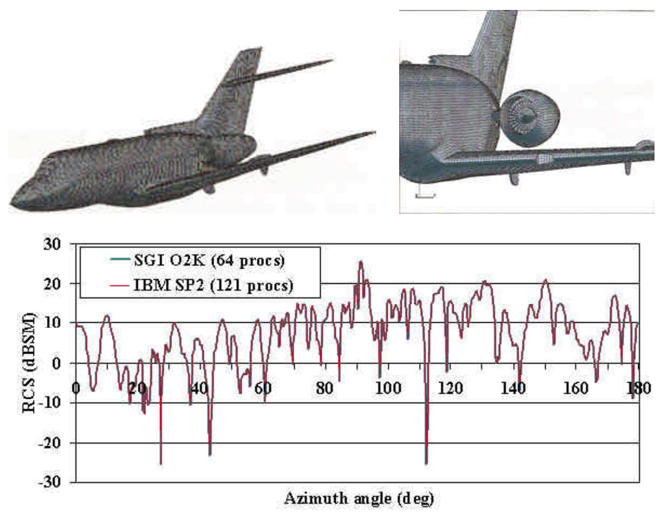
***Impact to DoD:** High performance computing codes were used to reduce turn around time between B-2 flights during Operation Allied Force.*

Objective

Radar signature prediction of large, complex targets is very important to warfighting. A hybrid finite element—boundary integral technique in curvilinear coordinates—has been devised that offers significant advantages over traditional techniques such as the method of moments, for performing such predictions. Our objective is to demonstrate the portability and scalability of this technique on HPC platforms. The computational advances of such a technique have additional diverse ramifications including the design of antennas, microelectromechanical devices, and high-speed computer and communication circuits.

Methodology

The curvilinear geometry discretization, employed by our finite element boundary integral code—SWITCH, results in far fewer unknowns per wavelength for a given accuracy compared to faceted geometry adopted by most other codes. SWITCH was made portable and scalable on most HPC platforms by interfacing with the public domain ScaLAPACK library, thus eliminating the need for commercial solvers with licensing fees. Further, collaborative work with scientists at Oak Ridge National Labs resulted in the development of a new out-of-core solver for the SGI Origin 2000 benefiting the entire computational electromagnetics community.



C-29 Radar Cross Section (2 GHz, horizontal polarization)

Results

The efficacy and portability of SWITCH has been demonstrated by developing solvers, with DoD/DoE funding, from the ScaLAPACK library resulting in optimal use of existing resources. The figure demonstrates code portability by depicting agreement between radar cross sections of the C-29 aircraft computed using the out-of-core ScaLAPCK solvers on 64 and 121 processors of the SGI Origin 2000 and IBM SP2, respectively. To complete the airframe analysis, SWITCH has been used to compute radar signatures of critical aircraft components at higher microwave frequencies. Such computations have played a paramount role in maintenance and operability of long-range strike aircraft, such as the B-2 bomber.

Significance

SWITCH was used to provide critical assessment data for the B-2 during Operation Allied Force to reduce turn around time between flights.

Computer Resources: IBM SP2 and SGI Origin 2000 [ASC MSRC]

CTA: CEA

JWCO: Precision Fires, Combat Identification

Scalable, Strongly-Coupled, Large Deformation Simulations of Fluid Structure Interactions

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Naval Research Laboratory (NRL), Washington, DC
V. Gamezo
Berkeley Research Associates, Springfield, VA
F. Felker
Livermore Software Corporation, Livermore, CA

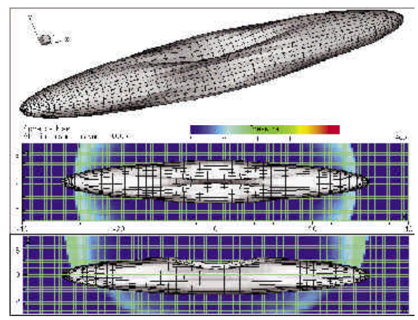
***Impact to DoD:** Using high performance computers and strongly-coupled software suites, DoD researchers are able to expand the knowledge base of fluid-structure interactions. This knowledge will assist in the development of new technologies for expeditionary operations and special warfare.*

Objective

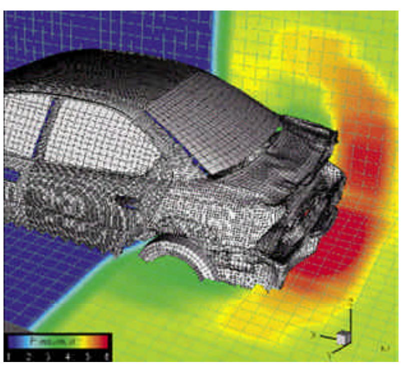
To develop and implement a high-performance, strongly-coupled, fluid-structure interaction software suite for modeling the large deformation, self-consistent response of geometrically complex structures to shocks and blasts; to quantify and improve survivability and lethality issues focused on fluid-structure interaction environments.

Methodology

A state-of-the-art Eulerian, finite-difference CFD code (FAST3D) has been fully integrated into a state-of-the-art finite-element CSM code (LS-DYNA3D) in a strongly-coupled fashion using the Dynamic Virtual Cell Embedding (DVCE) technique as the interface. This allows for the efficient and accurate computation of hydrodynamic flows about moving and deforming geometrically complex bodies and the response of those bodies to shocks and blasts.



Top and side view of the pressure field and the large deformation response of a thin, aluminum, tubular-shaped object impacted by a sperical blast from above



Response of an automobile to a large blast from the rear. This simulation has over 100,000 elements.

Results

Simulations were performed of the large deformation response of complex structures to blasts and shocks. The calculations show good scalability. Simulations of a spherical blast on a metal cylinder with internal stiffening ribs show good qualitative agreement with a conventional underwater blast on a similar structure. The figures illustrate the capability of modeling the large deformation response of structures and the self-consistent response of the fluid.

Significance

It is important to improve the knowledge base of fluid-structure interactions for engineering designs and to develop and demonstrate new technologies for expeditionary operations and special warfare. This code fills the need for scalable, high performance software for generic fluid-structure interaction problems where the nonlinear response of the fluid and structure are needed. The modular nature of the code allows for complex blast models and equations-of-state models (for both the medium and the structure) as well as simplified models.

Computer Resources: SGI Origin 2000 [ERDC MSRC]

CTA: CSM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Real-Time Scene Generation Techniques

K.G. LeSueur and E.E. Burroughs

Redstone Technical Test Center (RTTC), Redstone Arsenal, AL

K.R. Allred, D.R. Anderson, and K.M. Dennen

ERC, Inc., Huntsville, AL

***Impact to DoD:** High performance computers are being used to generate uniform, "real-world" scenes that will give testers, warfighters, and planners the additional tools to make value judgments about the development, improvement, and acquisition of infrared systems and to reduce the cost of doing live experiments.*

Objective

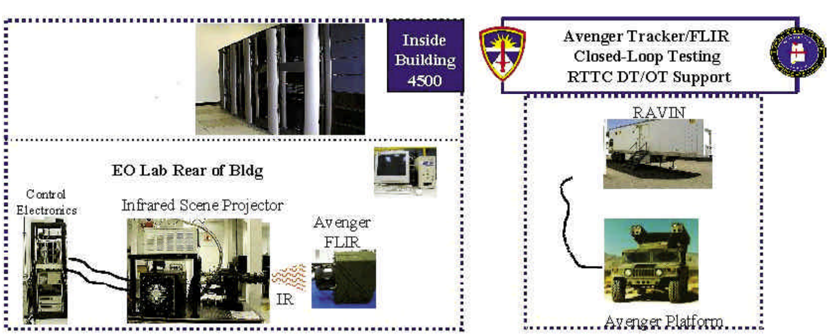
Redstone Technical Test Center (RTTC) engineers are providing real-time, synthetic, dynamic imagery input into multi-element scene projector arrays that is comparable to what a system under test would see in the real world. The engineers are realistically projecting "real-world" infrared imagery into the input aperture of a unit under test such as the AVENGER FLIR.

Methodology

In the context of electro-optical (EO)/infrared (IR) testing at RTTC, scene generation is the construction of radiometrically correct digital images representing real-world situations that one would encounter on the test range or battlefield. Imagery that is projected into these systems is generated with high performance computer resources using multi-treading techniques and multiple graphics pipes to achieve desired fidelity and frame rates. The RTTC has the requirement to project dynamic, infrared imagery to missile and target acquisition sensors under test. RTTC has taken an active role in evaluating and testing the Avenger's new slew-to-cue capability. This imagery must be of sufficient quality and resolution so that, sensors under test will perceive and respond just as they do to real-world scenes. These digital scenes are transmitted via fiber optic link to the RTTC Hardware-in-the-Loop (HWIL) facility for projection into the Avenger FLIR. The gunner views the virtual world by looking into the actual sight in the Avenger turret. As the gunner slew's the turret, this motion is communicated to the HPC scene generator and the scene changes based on the new gunner's perspective.

Results

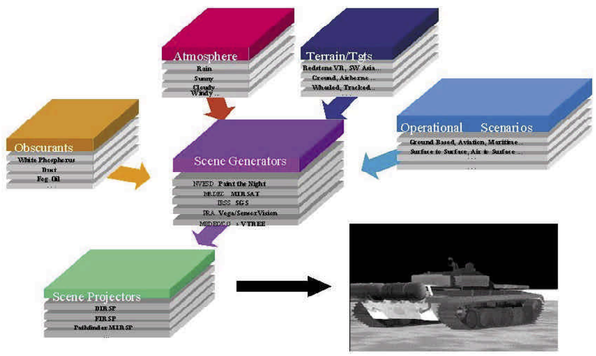
Real-time rendering of radiometrically correct imagery in a HWIL environment allows for the testing of detection, recognition, identification, and acquisition of threat targets. It also provides a high-speed, reliable, and flexible means of digitally processing IR images captured from an emitter array. This capability can be used to support AVENGER tracker and FLIR upgrades in the future. It can also be used in conjunction with current RTTC system tests, to perform a more robust, complete test of the AVENGER system.



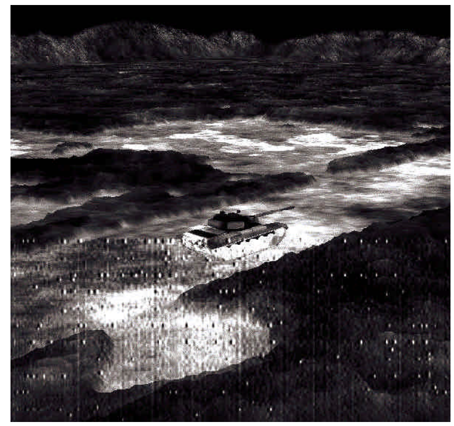
AVENGER Hardware-in-the-Loop (HWIL) configuration

Significance

This capability greatly reduces the cost of using expensive air threat targets typically used in test, with the same targets modeled in the virtual world. It will give testers, warfighters, and planners the additional tools to make valued judgements for development, improvement, and acquisition of fielded systems. It will also give testers, warfighters, and planners the additional tools to make valued judgements for development, improvement, and acquisition of fielded systems. In addition, prohibitively expensive field tests can be repeatedly performed in a laboratory environment at a reduced cost.



Components of Scene Generation and Projection System


Corrected and uncorrected image: Bottom half of image is uncorrected, top half of image is corrected

Computer Resources: SGI Origin 2000 , SGI Onyx2, and SGI Onyx2 Satellite [RTTC DC]

CTA: IMT

JWCO: Precision Fires

A Numerical Model for the Interaction of Elastic Waves With Buried Land Mines

C.T. Schroeder and W.R. Scott

Georgia Institute of Technology, Atlanta, GA

Impact to DoD: *DoD scientists are performing simulations on high performance computers to study how elastic and electromagnetic waves are used synergistically to detect buried land mines.*

Objective

A three-dimensional, finite-difference model for elastic waves in the ground has been developed and implemented for a massively parallel computer. Using the finite-difference model, the elastic waves in the ground and their interactions with the buried land mine are being investigated.

Methodology

The numerical finite-difference model has been developed as part of a project in which elastic and electromagnetic waves are used synergistically to detect buried land mines. In the acousto-electromagnetic sensor, a transducer placed on the surface of the ground launches elastic waves. The waves interact with a buried land mine and cause the surface above the mine to vibrate. A radar is mounted above the surface. The radar detects these vibrations and, thus, the mine.

In the finite-difference model, the elastic wave fields are computed on a three-dimensional discrete grid. When implemented on a parallel computer, this grid is divided into several sub-grids, and each sub-grid is assigned to one processor of the parallel machine. Figure 1 visualizes the distribution of processors across the computational grid. Here the elastic waves, due to a source placed at the upper front corner of the cube, are shown. As an example, the grid is divided into eight sub-cubes, each of which is assigned to one processor. The processors then compute the wave fields in parallel throughout their sub-cubes. The computations for the simulations are being performed on the ERDC MSRC Cray T3E parallel supercomputer. For the numerical simulations, the availability of a massively parallel computer is crucial. One simulation on a serial computer (a computer with only one processor) would take approximately 1,000 hours (which is equivalent to almost 42 days). Using the Cray T3E with its 544 processors, the actual time needed for the computations can be significantly decreased. If the computation load is shared among 256 processors which work in parallel, the 1,000 hours of computations would be reduced to less than four hours.

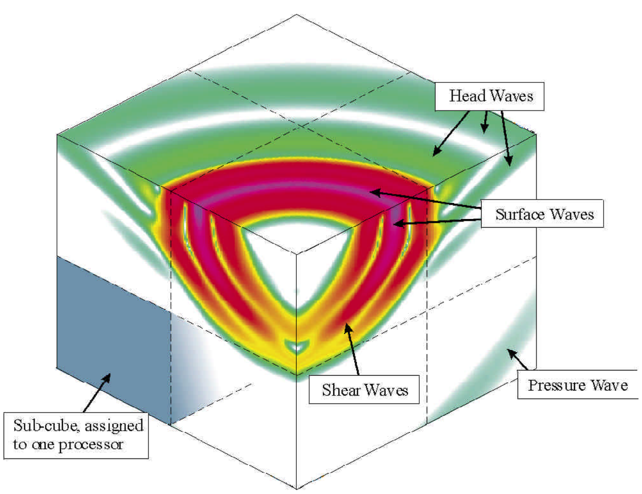


Figure 1. Division of the solution space in sub-spaces. Each cube is assigned to one processor.

Results

Figure 2 shows the elastic waves, interacting with a buried anti-personnel mine, on the surface plane and a cross section through the ground. The elastic waves are launched by a transducer placed on the surface and are scattered by the buried mine (indicated on the cross sectional plane). Both on the cross sectional plane and the surface plane, resonant vibrations are visible at the mine location, which causes the mine to radiate continuously. Similar resonances are also observed experimentally and can be used to distinguish the mine from clutter.

Significance

The numerical model plays a significant role in developing the acousto-electromagnetic sensor. Using the numerical model, the wave fields beneath the surface can be visualized while experimentally, the displacement can be measured only on the surface. Furthermore, the numerical model can easily be adjusted to different materials and to different arrangements (e.g., for different sources, different mines, various soil parameters etc.). Thus, in its flexibility the numerical model bears an inherent advantage over the experimental model.

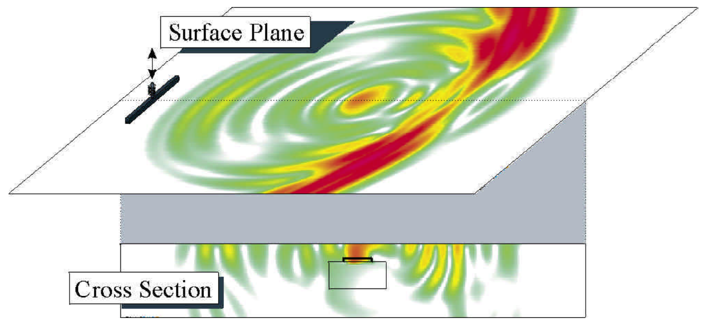


Figure 2. Elastic waves interact with a buried anti-personnel mine

Computer Resources: Cray T3E [ERDC MSRC]

CTA: CEA

JWCO: Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

Virtual Prototyping Confirms Benefits of a Proposed High Power Microwave Source Design Modification

2nd Lt J.D. Blahovec, L.A. Bowers, and J.W. Luginsland

Air Force Research Laboratory (AFRL), Kirtland AFB, NM

S.L. Colella and J.J. Watrous

NumerEx, Albuquerque, NM

Impact to DoD: *High performance computers are being used to virtual prototype high power microwave weapon design modifications significantly reducing cost and development time.*

Objective

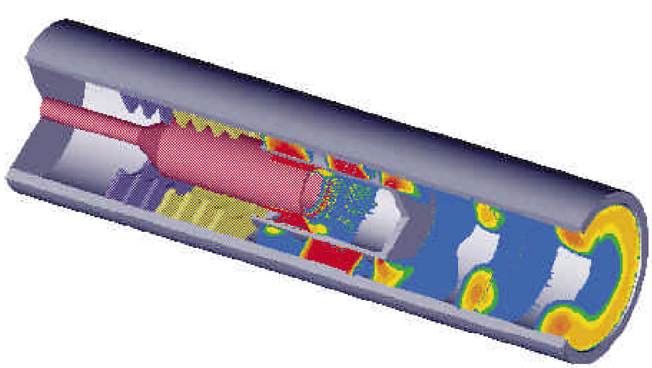
In the future, High Power Microwave (HPM) weapons will be used to gain a significant advantage over the enemy through Electronic Combat. HPM weapons may be used to disrupt or damage electronic systems, disabling enemy defenses and weaponry, with little or no collateral damage. Development of the sources for such devices is challenging because very high powers and small lightweight packages are required. Improved Concurrent Electromagnetic Particle-in-Cell (ICEPIC) may be used both for fine-tuning well-understood devices and for testing radical new designs. A DoD Challenge Project is applying a series of in-house research codes to the problem of virtual prototyping HPM devices. Such virtual prototyping may be used to reduce cost significantly and to reduce development time.

Methodology

ICEPIC, a three-dimensional parallel Particle-in-Cell (PIC) code, was developed to take advantage of the many parallel assets available to the DoD community. It is a portable, scalable software package that models low-density plasma in low-collisionality systems and is an appropriate choice for modeling the diode and cavity regions of HPM sources. ICEPIC was one of the first fully functioning, PIC codes to be implemented on a parallel platform.

Results

The Magnetically Insulated Line Oscillator (MILO) is a source that has been researched quite extensively and has been developed at the AFRL as a possible candidate for use in HPM weapons. A recent proposed design change to the MILO was expected to increase the output power and efficiency of the device. This design change required permanently modifying the device and several variations were simulated using ICEPIC. The



The geometry of a MILO and the radial electric field extremes in the extractor and waveguide regions of the device are shown in the figure. This figure was created using ICEPIC's output diagnostic data and Amtec's Tecplot v7.0.

results of these simulations confirmed that shortening the last vane in the slow-wave structure (right most yellow vane in the figure) would increase the output power and the efficiency of the device. This optimized MILO has been built according to the proposed changes and is currently undergoing testing.

Significance

Strict requirements will be placed on the performance and size of an HPM weapon in order to meet the needs of the warfighter. To obtain the optimal performance from an existing design, many design modifications need to be tested and validated. Virtual prototyping can be used to investigate these modifications thoroughly and decrease the time and cost involved significantly as compared to a similar experimental effort. As demonstrated here, ICEPIC has proven that it is capable of predicting the performance of proposed HPM source designs.

Computer Resources: IBM SP [ERDC MSRC] and SGI Origin 2000 [ASC MSRC]
CTA: CEA
JWCO: Precision Fires, Electronic Warfare

Assessing the Terrorist Attack on the U.S. Embassy in Nairobi, Kenya

J.D. Baum, E. Mestreau, H. Luo, and R. Lohner

Advanced Technology Group, Science Applications International Corporation, McLean, VA
George Mason University, Fairfax, VA

Impact to DoD: *DoD scientists are using high performance computers as a forensic tool to study blast damage to facilities in response to terrorism.*

Objective

Develop a fully integrated CFD and Computational Structural Dynamics (CSD) methodology for the time-dependent simulation of blast wave interaction with structures.

Methodology

The developed methodology will model the complete detonation, initiation and propagation, blast wave diffraction, and structural response phenomena (Figure 1). Processes modeled include: detonation of the conventional or nuclear weapons, blast wave propagation in the free field, blast diffraction about the structures, blast loading on the structures, the resulting structural response, wave modification due to structural response, and blast propagation through the responding structure.

The CFD methodology, FEFLO98, is a three-dimensional, adaptive, finite element, edge-based, Arbitrary Lagrangean-Eulerian (ALE) shock capturing methodology on unstructured tetrahedral grids, for the solution of the Euler and Reynolds-averaged turbulent, Navier-Stokes equations. The CSD methodology, DYNA3D, employs unstructured grids, a spatial discretization using finite element techniques, large deformation for the solids, explicit time integration, and several material models, kinematic options, and equations of state.

Results

The developed methodology has been applied successfully to both military and civilian applications. The results shown here model the terrorist attack against the U.S.Embassy in Nairobi, Kenya, August 7, 1998, that killed 224 people, including 12 Americans, and wounded thousands. The simulation modeled the denotation wave initiation, wave propagation, and diffraction about 92 buildings within a radius of 500 meters from the blast point, the maximum extent of observed damage. The simulation was conducted in two phases. In the first phase, the adaptive solver was used to propagate the blast wave until it completely

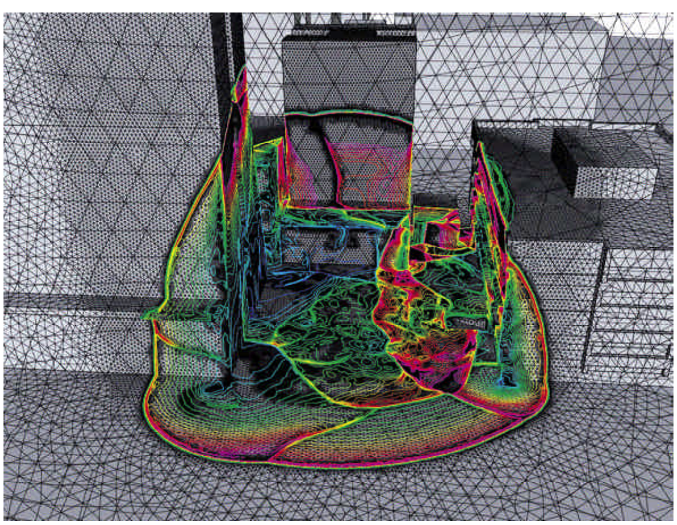


Figure 1. Superimposed pressure contours and adapted mesh on the surface at t=28.92 ms. This result shows the automatic mesh adaptation about the many diffracting shocks, yielding efficient resolution of the many shocks in the domain.

diffracted around the embassy building, a period of about 0.1 seconds. The fine-resolution adapted mesh (4.0 cm) contained about 120 million elements, and provided detailed blast waves (i.e., peak pressure and impulse) for the structural analysis. In the second phase, the non-adaptive approach was used to propagate the blast wave through the complete domain (Figure 2). The non-adapted solution included about 140 million elements. Four simulations were conducted using different charge sizes. For one of these charges, the simulation predicted 17.6% window breakage on several buildings located at a range of 400–500 meters. Post-attack survey showed 18.0% glass breakage for these buildings.

Significance

The coupled methodology enables the a-priori prediction of blast damage to underground command and control centers and other targets of military significance, thereby increasing targeting efficiency. Simultaneously, the methodology enables the cost-effective hardening of civilian and military facilities against terrorist attacks. Here, the numerical methodology was used as a forensic tool, to help pinpoint the size of the explosive charge.

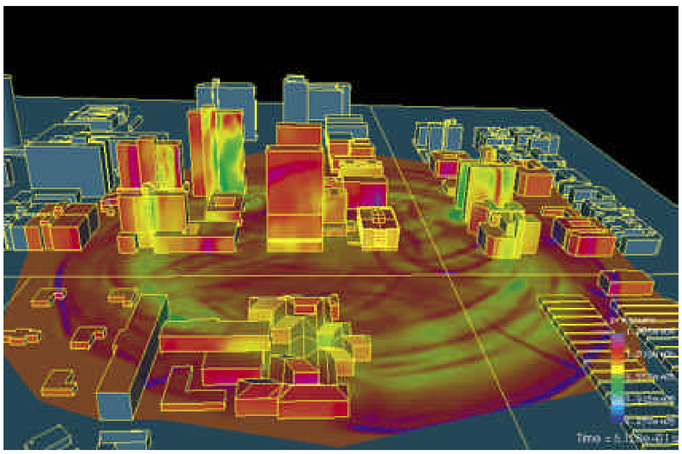


Figure 2. Pressure contours on the surface at t=0.512 seconds. This result shows many blast waves diffracting about and reverberating between the large number of buildings in downtown Nairobi, Kenya.

Computer Resources: SGI Origin 2000 [ASC and NAVO MSRCs]

CTA: CFD

JWCO: Military Operations 0n Urbanized Terrain, Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

ZNSFLOW CFD CHSSI Software

H. Edge, J. Sahu, W. Sturek, J. Clarke, D. Pressel, M. Behr, K. Heavey, P. Weinacht, and C. Zoltani

Army Research Laboratory (ARL), Aberdeen Proving Ground, MD

***Impact to DoD:** Under the CHSSI, high performance computers are being used to improve the primary modeling tool for missile aerodynamics at ARL.*

Objective

Develop a scalable version of zonal Navier-Stokes flow solver (ZNSFLOW) and add features that would enhance applicability/ease of use. Demonstrate the design utility of the software by solving current DoD priority viscous flow problems.

Methodology

Under the auspices of CHSSI, a suite of codes, now called ZNSFLOW, was developed to enable the calculation of aerodynamic problems of DoD interest. Based on a solver known as F3D, a fully vectorized Fortran 77 code was rewritten to provide scalable performance on a variety of architectures. Enhancements included dynamic memory allocation and optimized cache management. Emphasis was placed on user friendliness. The distributed interactive computing environment (DICE) graphical user interface (GUI) was written to allow some of the ZNSFLOW solvers̕ complex features to be easily employed and incorporates menu-based help. For example, the solver allows for one-on-one overlaps between grid zones in any direction. The GUI makes the setup for this generalized data exchange intuitive and also provides simple error-checking capabilities. DICE allows the user to visualize the flow field at his or her desk as it is being computed on a high performance computer without the need to copy the large flow field data set from the host computer. In addition, the solver can perform computations with a Chimera composite grid discretization technique. The difficulty of using turbulence models with the Chimera technique has been overcome by implementing a pointwise turbulence model.

Results

The code has been successful in calculating flow fields starting with flows around missiles at large angles of attack, guided multiple launch rocket system (MLRS) missiles (Figure 1), and the flow field about ten brilliant antiarmor (BAT) submunitions ejected from an Army tactical missile (ATACM). ZNSFLOW has also been tested

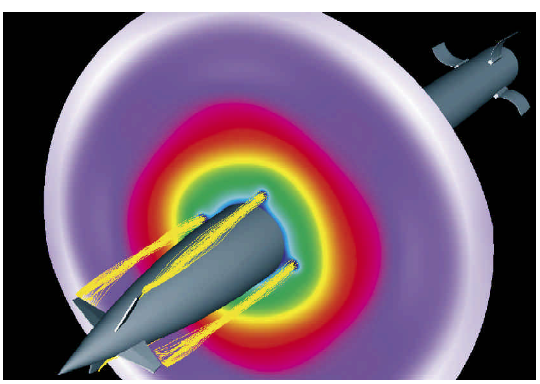


Figure 1. Guided MLRS pressure contours and particle traces

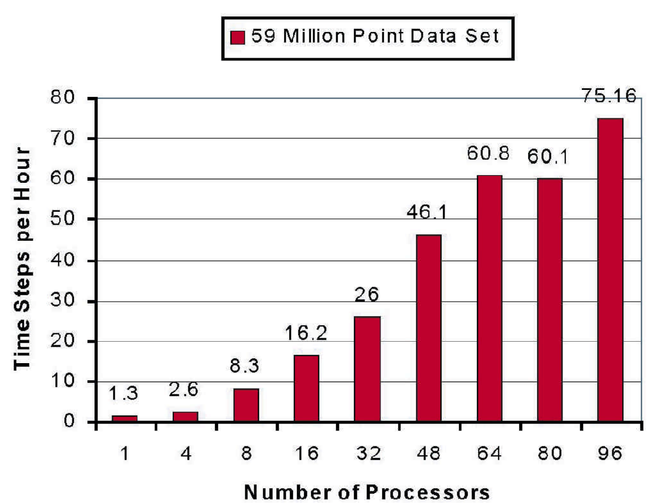


Figure 2. Performance for 59-million-point data set on SGI Origin 2000

with a grid size of 59 million points (Figure 2), and the performance achieved on a SGI Origin 2000 with 96 processors is 18 times that on a single Cray C-90 processor. Experimental verification of the flow field predictions gives confidence in the capability of the code.

Significance

ZNSFLOW provides a computational tool that can produce fast, accurate results for complex configurations on today's high performance scalable computers. ZNSFLOW has demonstrated its capability in computations for BAT and guided MLRS. The ability to model extremely large data sets, such as the 59-million-point test case, indicates that ZNSFLOW is capable of modeling more complex cases in the future. This software has evolved to be the primary production modeling tool for missile aerodynamics at ARL and is receiving increasing interest from other DoD researchers.

Computer Resources: SGI Origin 2000 [ARL MSRC] and Cray T3E [AHPCRC DC]

CTA: CFD

JWCO: Precision Fires

Meshfree Methods for Prediction of Structural Damage

W.K. Liu, T. Belytschko, S. Hao, S. Li, and K.T. Danielson

ARL-AHPCRC at Northwestern University, Evanston, IL

Impact to DoD: *DoD engineers are using high performance computers to model the structural damage caused by an exploding weapon so that large, detailed analysis can be performed quickly.*

Objective

To develop meshfree methods for the large deformation analysis of solids and structures that can accurately model the development and arbitrary evolution of shear bands, fracture, and fragmentation.

Methodology

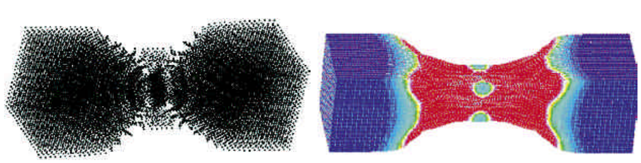
Two and three-dimensional codes have been developed at Northwestern to simulate such events using both Reproducing Kernel Particle Method (RKPM) and Element Free Galerkin (EFG) meshfree methods. Elasto-Plastic and viscoelastic constitutive models, including multiple scale methods, have been implemented into the software for complex large strain behavior of metals and concrete. Coarse-grain parallel paradigms with MPI have been developed for effective use of large numbers of parallel processors on DoD HPC platforms.

Results

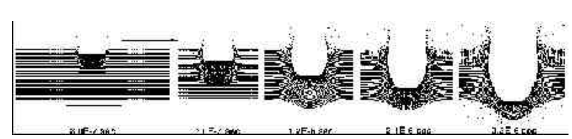
Simulations like the shear band development and penetration problems shown in the figures were performed with the meshfree method software. Analysis with 128 processors of Cray T3E showed a speedup of approximately one hundred compared with the analysis on a single processor. Complex analyses that could require hundreds of cpu hours were thus demonstrated to be performed in several hours or less.

Significance

A major challenge in lethality and vulnerability analyses is the automatic modeling of cracks and shear bands that develop and grow arbitrarily within a structure. The ability to model crack and shear band growth is essential to first principles modeling of weapons effects. The attributes of meshfree methods endow these methods with great promise for treating this class of problems. Meshfree methods inherently possess advantages for treating fracture such as the natural development of interior surfaces of discontinuity (e.g., cracks, shear bands) and the ability to deal with larger deformations than conventional finite element and finite difference methods. Using parallel computing, large, detailed analysis can be performed more rapidly allowing more in-depth design investigations.



RKPM meshfree prediction of three-dimensional shearband development in a tensile specimen



Simulation of a penetration event with a multiple scale RKPM meshfree method

Computer Resources: Cray T3E [AHPCRC DC]

CTA: CSM

JWCO: Precison Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

Improving Missile Control Jet Design

H.B. Ebrahimi

Sverdrup Technology, Inc., Arnold Engineering Development Center (AEDC), Arnold AFB, TN

Impact to DoD: *DoD engineers are using high performance computers to simulate the effects control jets have on missile flight to improve missile flight dynamics.*

Objective

Control jets are used to maneuver the missile towards its target, which might be an incoming reentry vehicle. Successful interception requires an accurate knowledge of the thrust produced by the jet. However, the thrust of a rocket motor as obtained from a static test is modified considerably by interaction of the jet plume with the oncoming hypersonic stream. Further, the control jet must pulse on and off, and the transient thrust may differ from the steady state thrust. The purpose of the present computations was to assess the significance of the unsteady thrust.

Methodology

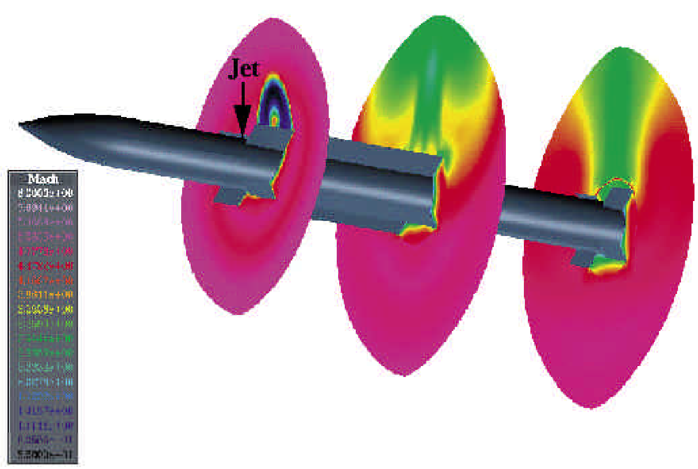
The commercial flow solver GASP was run in a time-accurate fashion for a finned missile configuration with a thruster located ahead of the forward fins. The grid contained 3 million points and 14 meshes. The Navier-Stokes solution assumed calorically perfect gas.

Results

Thrust time curves, including all viscous jet interaction effects, were generated for the transient jet startup and shutdown. Significant excursions from the steady state thrust level were observed in the solutions, and the time for the jet thrust to react to the transient was significant relative to the length of the jet-on time.

Significance

The primary conclusion is that transient effects are important for long-body finned missiles and must be accounted for in missile design. This is particularly relevant to the Navy Theater-Wide Missile system now under development.



Computer Resources: HP Exemplar [AEDC DC]

CTA: CFD

JWCO: Information Superiority, Precision Fires, Joint Theater Missile Defense

Damage Simulations in Hard and Deeply Buried Targets Due to Internal Blast and Shock Loading

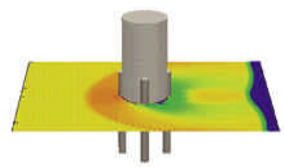
G.W. McMahon and B. Armstrong

Engineer Research and Development Center (ERDC), Vicksburg, MS

Impact to DoD: *DoD engineers are using high performance computers to simulate an explosion in a tunnel system. The results will provide a means to predict functional defeat for weapons of mass destruction storage and production facilities.*

Objective

The Joint Warfighting S&T Plan Counterproliferation objective includes counterforce defeat of hardened Weapons of Mass Destruction (WMD) storage and production facilities. Many of these facilities are located in deeply buried tunnels in rock. One attack option is to penetrate the rock overburden or the door system and detonate the weapon inside the tunnel. The airblast propagation within the tunnel system has the potential to cause significant damage to mission critical and support equipment, resulting in a functional defeat of the facility. HPC analyses were performed to simulate an explosion in a tunnel system and the resulting damage to a storage container. The computed results were compared to results from a field experiment.



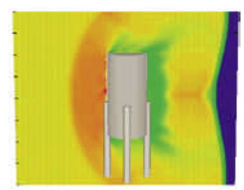


Figure 1. Calculation of load on storage tank structure

Methodology

A scalable, explicit, Eulerian hydrodynamic code was used to determine the airblast loads from a weapon detonation in a tunnel system on a storage tank. Calculations were performed using 10,000 CPU hours on 256 processors of the Cray T3E at ERDC. A two-dimensional computation was used to approximate the airblast in the tunnel. At a distance of approximately two tunnel diameters from the tank, the grid was rezoned to obtain the three-dimensional flow around the tank. The loads from these calculations were used as input to a large deformation, explicit, Lagrangian, finite-element code to calculate the response of the tank.

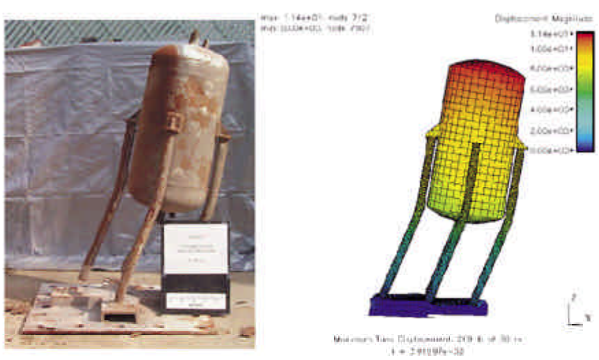


Figure 2. Comparison of calculated and experimental response of storage tank structure

Results

The results of the calculations were used to determine the range at which failure and severe damage of the tanks and other equipment would occur in a large-scale field experiment. Figure 1 shows the calculations of the loads on a tank. Figure 2 shows the severe damage response of the tank in the experiment compared to the calculation results. Clearly, the results are in excellent agreement, and this analysis effort resulted in a very successful field experiment.

Significance

This research will contribute to the Department's ability to defeat WMD storage and production facilities by significantly improving analysis and predictive tools.

Computer Resources: Cray C90 and Cray T3E [ERDC MSRC]

CTA: CSM

JWCO: Combat Identification, Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction, Hard and Deeply Buried Target Defeat

Ordnance Detonation and Penetration Mechanics Modeling

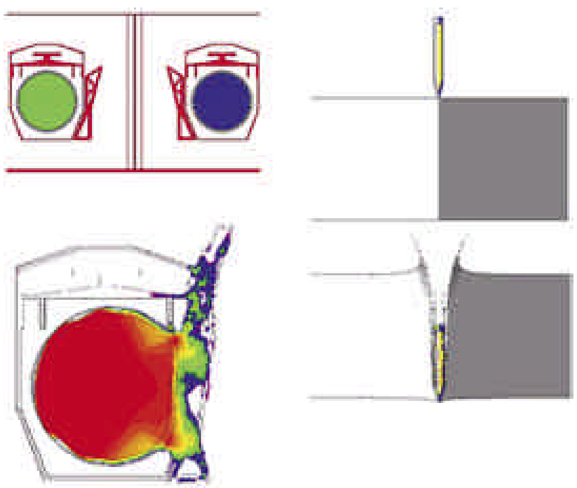
E.D. Cykowski

Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, CA

Impact to DoD: *High performance computers have been used to successfully model the impact of high-explosive warheads, reducing the number of live tests required, at significant savings over live ordnance testing.*

Objective

To evaluate the sympathetic detonation, bullet impact, and fragment impact response of high-explosive warheads and compare to test data to satisfy the requirements of MIL-STD-2105B, 12 January 1994, Military Standard, Hazard Assessment Tests for Non-Nuclear Munitions; to model the penetration of air-launched weapons into reinforced concrete and steel targets; and to reduce the number and type of full-scale live ordnance tests.



Methodology

The ordnance detonation and penetration mechanics modeling was performed with the CTH hydrocode from Sandia National Laboratories, which is installed at ARL and the other high performance computing centers. CTH is an Eulerian, finite-volume code for modeling solid dynamics problems involving high-explosive detonations, shock-wave propagation, multiple materials, and large deformations in two- and three-dimensions.

Results

Good correlation between test and simulation results for the insensitive munitions and penetration mechanics models were obtained for numerous warhead designs.

Significance

As a result of the modeling success, a reduction in the number of full-scale tests required for new ordnance designs is possible. The modeling cost is typically in the range of 1% to 5% of the cost of testing full-scale, live ordnance.

Computer Resources: SGI Origin 2000 and Cray T90 [ARL MSRC]

CTA: CSM

JWCO: Precision Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

Novel Lethal Mechanisms for Missile Applications

S.J. Schraml and E.W. Kennedy

Army Research Laboratory (ARL), Aberdeen Proving Ground, MD

***Impact to DoD:** ARL is investigating kinetic energy technologies in tactical missiles to increase lethality while reducing cost.*

Objective

The ARL is currently investigating the use of novel penetrator concepts in tactical missile applications. The objective of the program is to develop and/or exploit novel kinetic energy penetrator technologies as lethal mechanisms for missile systems to increase lethality while reducing size and weight. An important aspect of this effort is the integration of missile components as a part of the lethal mechanism.

Figure1. Experimental radiograph of missile nose cone impacting a target

Methodology

The computational methodology is based on the Eulerian finite-volume method. CTH is an Eulerian finite-volume code for modeling solid dynamics problems involving shock wave propagation, multiple materials, and large deformations in one-, two-, and three-dimensions. A two-step solution scheme—a Lagrangian step followed by a remap step—is used. A single program multiple data paradigm with explicit message passing between computational subdomains is used to map the global computational domain onto scalable architectures.

Results

Large-scale, finite-volume simulations of projectile/target interactions are being used in concert with an experimental program to assess the dynamic response and resulting damage to reacting targets when impacted by missile structure components at high velocities (Figure 1). Comparison of the computed results to the experimental data at discrete times during the interaction provides a validation of the computational approach for problems of this type. Successful validation of the approach results in the use of computations to study numerous additional configurations that would be too costly or time consuming to conduct experimentally. Furthermore, the amount of data that can be obtained from experimentation alone is limited. The simulations provide insight into the projectile/target dynamics over a wide range of time steps that are impossible to measure experimentally, providing a complete picture of the penetration event (Figure 2).

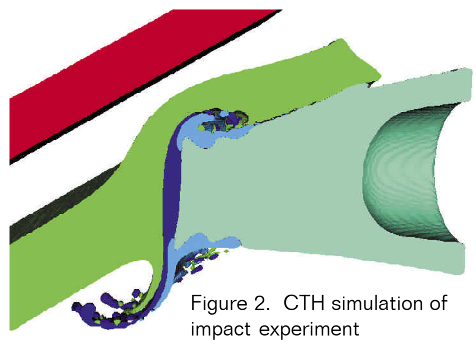


Figure 2. CTH simulation of impact experiment

Significance

This research effort benefits the Precision Fires Joint Warfighting Capability Objective. The combined experimental/computational program is being used to identify the potential benefit or degradation associated with the interaction between missile components and the target. Computational parametric analyses can be used to identify key features of projectile/target interactions that may be exploited to enhance the lethality of the overall missile system. Judicious use of numerical simulations steers the experimentation toward configurations with greatest potential payoff, reducing the cost of the overall research program.

Computer Resources: SGI Origin 2000 and Sun E10000 [ARL MSRC]

CTA: CSM

JWCO: Precision Fires

Response Predictions for Structure Collapse Experiments

T.L. Bevins, J.T. Baylot, H.W. Johnson, and R.L. Hall
Engineer Research and Development Center (ERDC), Vicksburg, MS

***Impact to DoD:** DoD scientists are using high performance computers to simulate and analyze blast damage so methods can be developed to evaluate the safety of troops housed in conventional structures and to improve safety.*

Objective

To develop methods of evaluating the safety of troops housed in conventional structures and to develop methods of improving safety. Analyses were performed to determine the explosive charge standoff required to cause the desired level of damage in two of the experiments.

Methodology

The DoD, Office of Special Technology, Technical Support Working Group sponsored a series of 1/4-scale experiments modeling a portion of a four-story, reinforced concrete-frame structure. The Defense Threat Reduction Agency was the technical manager for the program.

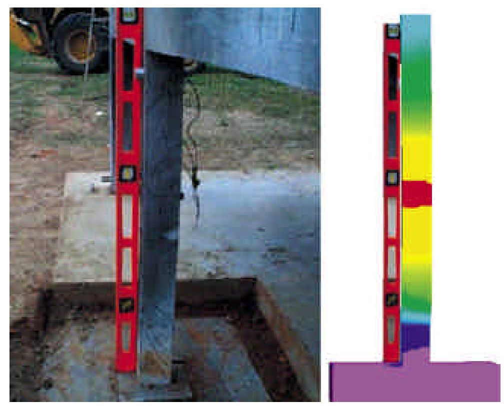


Figure 1. Xnview: Results without walls

A scalable, Eulerian explicit hydrocode was used to determine the airblast pressure loads applied to all structural members of the 1/4-scale structural model. Simulations were performed using 120 processors of the Cray T3E. Simulations were performed with and without exterior walls at several different explosive standoff distances. Airblast loads from each of the analyses were input into a finite-element analysis to predict structural damage. These analyses were performed on the Cray C-90 using a large-deformation, explicit, Lagrangian, finite-element computer code.

Results

Figure 2. Xnview: Results with walls

Analysis results were used to select the charge standoff to be used in two of the experiments. A standoff was selected such that significant damage (but not failure) would occur without exterior walls and failure would occur with exterior walls. The predicted column response matched the two subsequent experiments very well (Figs. 1 and 2). This analysis effort led to improved experiments that provided data to support the Combating Terrorism Joint Warfighting Capability Objective.

Significance

The results from these experiments will be used to improve the safety of troops housed in conventional structures.

Computer Resources: Cray T3E and IBM SP [ERDC MSRC]
CTA: CSM
JWCO: Combating Terrorism

Other

Development Technologies to Counter Chemical/ Biological Weapons

Chemical/Biological Defense

- detection
- protection
- decontamination
- modeling and simulation
- medical chemical/biological defense

Platform and System Technologies

Ground Vehicles

- land combat and tactical vehicles
- amphibious vehicles
  - propulsion and power
  - chassis and turret structures
  - vehicle subsystems

Sea Vehicles

- surface ship combatants
- submarines
  - maneuvering and seakeeping
  - power and automation
  - structural systems

Space and Launch Vehicles

Space Platforms

- spacecraft systems technology
- autonomy
- space vehicles technology
- launch and transfer
- debris and contamination

Weapons of Mass Destruction Defeat Payload Development

P.A. Hookham, C.T. Nguyen, and D.W. Lim

Titan Corporation, Chatsworth, CA

***Impact to DoD:** DoD engineers are using high performance computers to assist in the development of payloads for air-dropped munitions which destroy or deny the use of WMD weapons while minimizing the associated collateral effects.*

Objective

To assist in the development of payloads for air-dropped munitions which destroy or deny the use of biological or chemical warfare agents while minimizing associated collateral effects.

Methodology

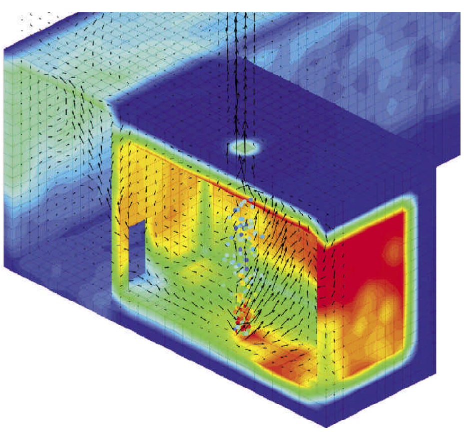
The Multi-phase, multi-material Adaptive Zoning (MAZe) computational fluid and solid dynamics code can model the motions of gases, liquids, solids (in a continuum sense), or multi-phase mixtures. The code is optimized for simulating highly transient, compressible flows, such as detonations, efficiently through use of an automatically adaptive computational mesh. The code solves the Reynolds-averaged Navier Stokes equations using a high-order, finite-volume Total Variation Diminishing (TVD) numerical scheme.

Results

These calculations have helped support the development of improved payloads for neutralizing WMD targets. This support has consisted of calculations to help design tests of new weapon fills and evaluate data from those tests, as well as studies of the effectiveness of weapon payloads when used against WMD targets. Payloads under investigation and/or development include high temperature incendiaries, chemical neutralizers, low-blast explosives, or combinations of these. The calculations have demonstrated that these payloads have the potential to destroy or deny the use of WMD materials while producing much lower collateral effects than conventional high explosive payloads.

Significance

The DoD is making significant strides in developing air-dropped munitions which are able to destroy WMD targets while minimizing collateral damage.



This figure shows the results of a calculation of an incendiary payload burning in a structure containing a BW agent simulant. (The walls of the structure facing the viewer are not shown.) The colored circles represent solid products from the combustion of the incendiary, where the color indicates the temperature of each particle. The colored contours plotted on solid surfaces show the air temperature adjacent to the surface. The black arrows indicate velocity plotted on a plane intersecting the computational domain.

Computer Resources: Cray C90, Cray T90 [NAVO MSRC] and Cray SV1 [DTRA]

CTA: CFD

JWCO: Precision Fires, Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

Real-Time Processing of Hyperspectral Sensor Data

A.I. Ifarraguerri

Edgewood Chemical and Biological Center, Aberdeen Proving Ground, MD

Impact to DoD: *DoD scientists are using high performance computers to evaluate the next generation of passive standoff chemical warfare agent detectors which will be able to assess and disseminate threat information more quickly by providing the needed data analysis in real-time.*

Objective

The next generation of passive standoff chemical warfare (CW) agent detector is being conceived as an imaging device. The advantages of such a system over the current generation of systems include inherent background measurements (through the multiple fields of view provided by the imaging capability), cloud mapping capability, and lower false alarm rate. By correctly exploiting the added spatial information we can increase the probability of detection (and consequently reduce the probability of false alarms). The associated next-generation processing techniques will include adaptive spectral filtering for initial detection, quantitative transmittance retrieval for cloud optical depth estimation, cloud ranging, and methods for analyzing data with unknown chemical species. Adaptive spectral filtering is an improvement upon the technique currently used. It takes advantage of the added spatial dimension provided by imaging spectrometers by computing local statistics in order to mitigate the effects of interferences. This allows the spectral filter to adapt to both gradual and sudden changes in the scene statistics. An important issue with implementation of adaptive filtering is computational load. This is a challenge for most single-processor computers, but parallelization can provide the necessary performance.

Methodology

A Single Instruction, Multiple Data (SIMD) parallel model was used given the data-intensive nature of the problem and the fact that iterations are computationally independent. A Boss group retrieves the image data and distributes it to multiple Worker groups. A Display group is given the task of displaying the output image. Figure 1 shows a conceptual diagram of the process groups and their connections. An optimized implementation of the algorithm written in the MATLAB language was directly parallelized using the RTExpress software from Integrated Sensors, Inc. RTExpress is a compiler and runtime environment that allows a MATLAB script to be compiled, and then executed in real-time on parallel High Performance Computers (pHPC) using the MPI.

Results

A performance goal of 20 milliseconds per line (on the average) was dictated by the assumed hyperspectral imaging sensor specifications. This goal was achieved with 1 Boss and 8 Worker processes. Benchmarking shows that execution times for RTExpress decrease linearly with the addition of Worker groups until the overhead of the added processors overcomes the benefits of increased computation capabilities. The best

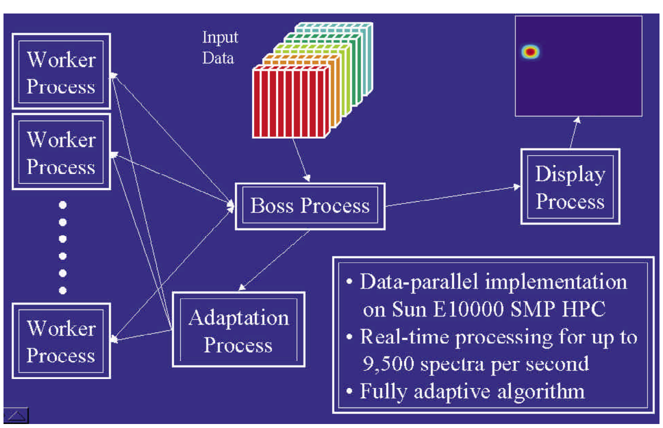


Figure 1. Diagram of parallelization model for real-time hyperspectral sensor data processing

average execution time, 13.4 ms/line, resulted from 1 Boss process and 10 Worker processes. This execution time corresponds to a frame rate of 74.6 Hz, giving an equivalent maximum throughput of 9,552 spectra per second. The execution time per line with parallel processing is significantly lower than with the serial implementation in MATLAB (100 ms/line). Figure 2 contains plots of the benchmarking results.

Significance

This work extends the Joint Services' capability for standoff detection of chemical agents and the ability to assess and disseminate threat information quickly by providing the needed data analysis in real-time, thus reducing the overall latency.

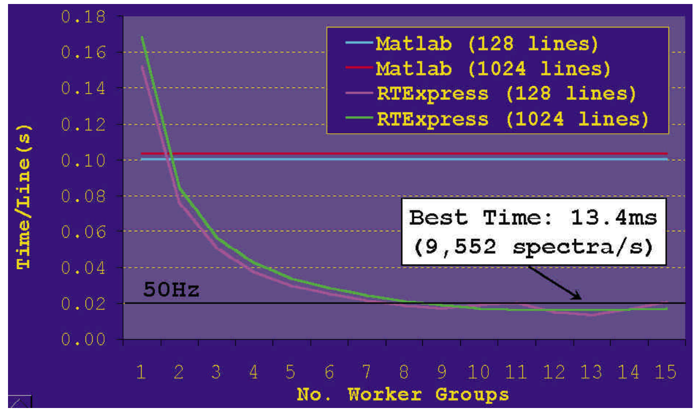


Figure 2. Benchmarking results

Computer Resources: Sun E10000

CTA: SIP

JWCO: Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

Contaminant Transport Modeling in Complex Urban Environments

B.Z. Cybyk, J.P. Boris, T.R. Young, Jr., C.A. Lind, and Y.T. Fung

Naval Research Laboratory (NRL) , Washington, DC

C.F. Cox

Lamar University, Beaumont, TX

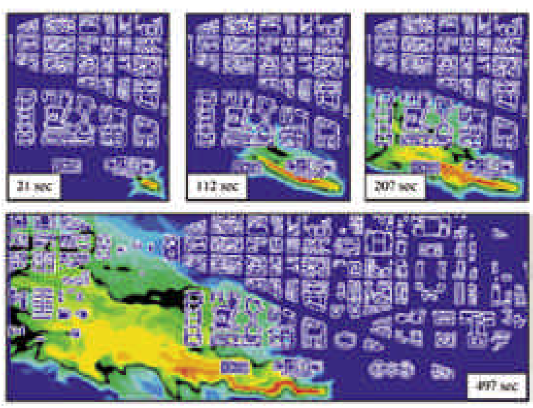
Impact to DoD: *DoD scientists, using high performance computing resources, have developed a contaminant transport model to study the effects of chemical/biological agents released into the atmosphere; the results can support consequence management operations.*

Objective

Further develop and mature a portable, complex geometry, contaminant transport model aimed at supporting consequence management operations for chemical/biological (C/B) incidents.

Methodology

The CFD code FAST3D-CT, is an extension of the CHSSI version of FAST3D, solves the dynamic transport equations for air and airborne contaminants. Multispecies particle and gas phase contaminants can be initialized, sprayed, or injected from localized sources, transported and diagnosed without restarting the model. A sophisticated turbulence model ensures that the flow correctly adapts to complex terrain with vertical and re-entrant surfaces. The need for rapid and inexpensive digital specification of complex geometry and subsequent grid generation led to the development of a new tile-based method of database generation and integration of the grid generator with the flow solver. To account for meteorological effects, the model is coupled to NRL's COAMPS mesoscale atmospheric model.



Contaminant from point source driven through downtown Washington DC by forecasted winds

Results

An interior-exterior-mesoscale C/B modeling capability that couples FAST3D-CT with COAMPS was demonstrated using an urban release scenario involving downtown Washington, DC. Using DoD Challenge Project resources, an external release scenario in a 2 km by 3.6 km region of the DC Mall, driven by forecasted winds from COAMPS, was computed to 5 m resolution via 12.2 million grid points.

Significance

The Navy, Marine Corps, DoD (and U.S.) require a modeling capability to counter the threat to high-profile targets from the proliferation of C/B weapons. Potential targets include strategic U.S. and coalition military sites, urban locations, and highly populated civilian areas. Such a modeling system must account for complex physical processes and varying meteorological conditions in geometrically-complex environments to effectively support consequence management doctrine, training, and operations. This effort contributes to the framework for a comprehensive, high-resolution, contaminant transport capability.

Computer Resources: SGI Origin 2000 [NAVO MSRC] and Convex Exemplar [NRL DC]

CTA: CFD

JWCO: Military Operations on Urbanized Terrain, Joint Readiness and Logistics and Sustainment of Strategic Systems, Chemical/Biological Warfare Defense and Protection and Counter Weapons of Mass Destruction

Rotating Marine Propulsor Simulation

C.K. Oh and W.C. Sandberg

Naval Research Laboratory (NRL), Washington, DC

R. Lšhner

George Mason University, Fairfax, VA

Impact to DoD: *Researchers can accurately simulate the efficiency and quiteness of submarine and ship propulsors.*

Objective

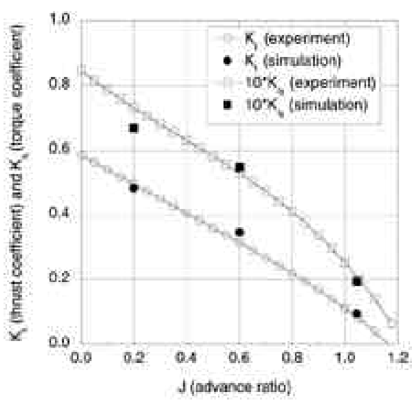
To develop the numerical techniques necessary to effectively simulate turbomachinery flows in a rotating frame of reference and to demonstrate the numerical ability to compute an accurate solution for the highly complex flow field around a rotating marine propulsor.

Methodology

A three-dimensional, finite-element CFD code, FEFLO, was used on unstructured tetrahedral grids. FEFLO was parallelized for use with shared and distributed memory computer architectures. Scalability has been demonstrated using various platforms such as the SGI Origin 2000, IBM SP2, and HP Examplar. A rotational periodic boundary condition was developed and included in the code in addition to the translational cascade periodicity. Also, a rotating frame of reference was included in the code by adding Coriolis and centrifugal forces in the equation set to describe the flow behavior relative to a rotating propulsor.

Results

The developed methodology has been applied successfully to an LPD-17 model propulsor. Three different flow conditions were selected by changing incoming water velocity. The pressure distribution over the blade surfaces and hub are in good agreement with the incompressible flow physics. The numerical results were compared with the experimental data and showed good agreement with thrust and torque coefficients as a function of advance ratio.



The simulation results for the rotating marine propulsor are compared with experimental data for the cases of J = 0.2, 0.6, and 1.05 in terms of thrust and torque coefficients. The RPM of the propulsor and freestream velocity of incoming water are 950 and 12 ft/s, respectively.

Significance

The developed techniques can be applied for the numerical simulations not only to gas turbine engines and pumps but also to submarine and surface ship propulsors.

Computer Resources: SGI Origin 2000 [ARL MSRC and NRL DC]

CTA: CFD

JWCO: Precision Fires, Joint Readiness and Logistics and Sustainment of Strategic Systems

Ballistic Shock Propagation

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R. Namburu

Army Research Laboratory (ARL), Aberdeen Proving Ground, MD

K. Bishnoi

Tank-Automotive Research, Development and Engineering Center (TARDEC), Warren, MI

Impact to DoD: *DoD engineers are using high performance computers to numerically simulate the impact weapons have on the armor of tanks and other military vehicles.*

Objective

The overall objective is to develop an accurate numerical methodology to predict ballistic shock propagation in armored vehicles. The present study discusses comparison of numerical simulation results with the Megahertz plate experiment.

Methodology

The numerical success of this problem depends on (a) the accurate representation of the impact load condition and (b) the ability of the finite-element (FE) mesh, in conjunction with a suitable constitutive model, to capture the wave propagation phenomena. For the former, three different approaches were studied: (1) explicitly defining the fragments (initial conditions, i.e., in-flight velocity, (2) using an equivalent loading function, such as a pressure-time history, that approximates the magnitude and nature of the impacting body, and (3) using the direct momentum deposition. For the latter, meshes of different density were constructed and numerically tested. A 2-million continuum FE mesh was the best suited for this study. Once the results were verified with available experimental data, the analysis was extended to the Ballistic Shock Simulator (BSS). The scalable CHSSI CSM software, ParaDyne, was used for all the simulations. The load distribution varied from 32 to 96 processors on the Origin 2000 at ERDC.

Results

Agreement between the experimental and the numerical data for the fragment impact on the steel plate was obtained within an allowable tolerance. Damage, deformation, strain, and other indicative variables were compared for both the experimental and the numerical data. Figure 1 shows the standing wave distribution built-up within the plate at 2 msec after impact. Figure 2 shows comparison of the response spectrum between the numerical and experimental data. The front end (zoom-in) of the BSS is shown in Figure 3 with

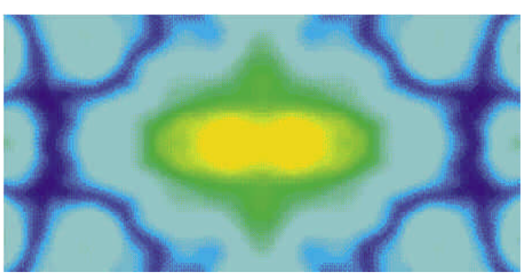


Figure 1

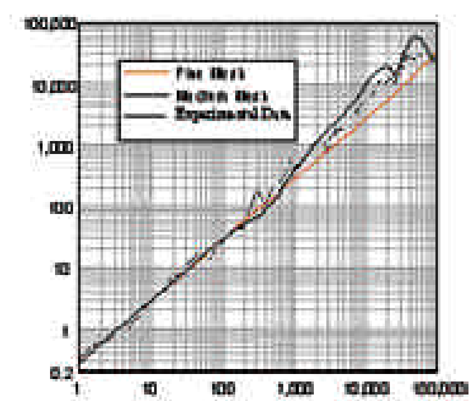


Figure 2

the impact plate situated at the potential strike-impact location. The load representation for cases (1) and (2) is also schematically illustrated. Partition and numerical outputs at the middle of the BSS are shown in Figure 4.

Significance

The use of scalable software and hardware leads to the successful simulations of the problems stated above. Experimental data are used to validate the numerical analyses. These studies constitute significant advances in the numerical analysis of nonlinear problems and, also, provide insight into the ballistic shock propagation characteristics of simple and complex structures.

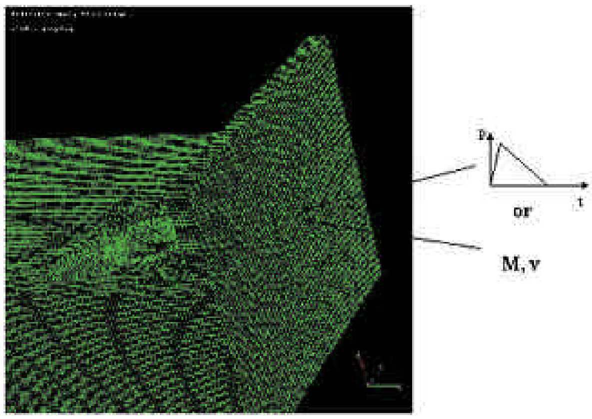


Figure 3

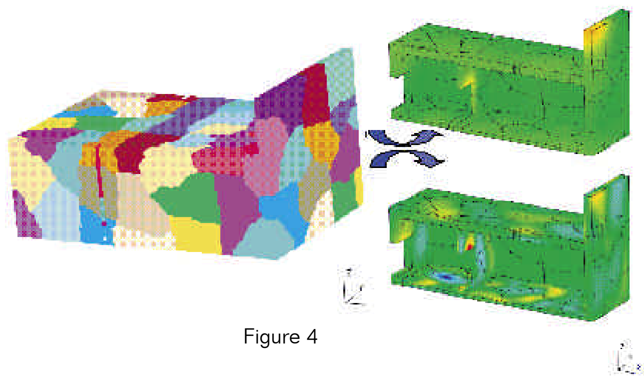


Figure 4

Computer Resources: SGI Origin 2000 [ERDC MSRC]	
CTA: CSM	
JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems, Precision Fires	

TARDEC Expands Real-Time Modeling of Ground and Tracked Vehicles

M. Brudnak, P. Nunez, M. Letherwood, and R. Romano

Tank-Automotive Research, Development and Engineering Center (TARDEC), Warren, MI and Realtime Technologies, Inc

Impact to DoD: *High performance computers make it possible to link several simulators together to create a synthetic environment to evaluate prototype designs and vehicle modifications. These models can be run at a fraction of the time and cost of corresponding physical processes; they can also be operated closer to a vehicle's upper performance without endangering equipment or lives.*

Objective

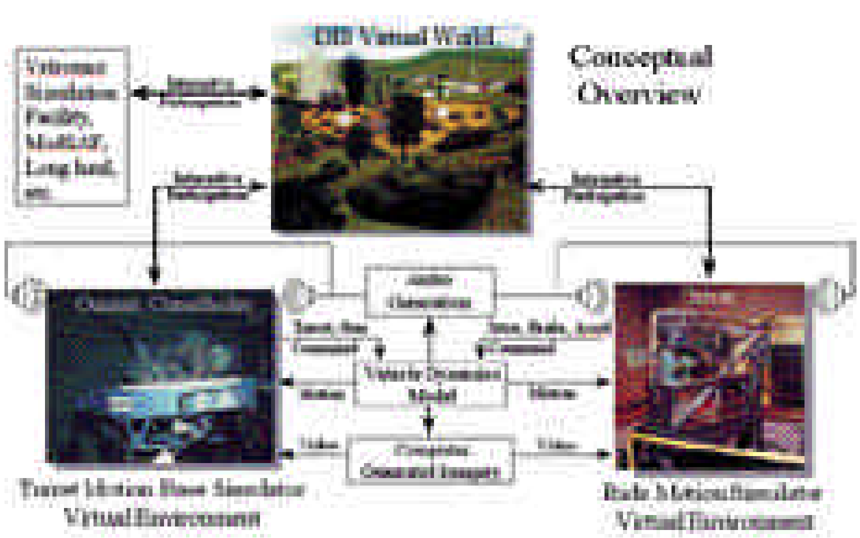
TARDEC engineers are using simulations to automate the process of generating and implementing real-time, engineering-fidelity ground vehicle models and hardware/operator-in-the-loop capabilities. These capabilities can be used to reduce vehicle model development, implementation, and application turn-around times as well as assessing vehicle performance, evaluating design modifications, and investigating soldier/ machine interfaces.

Methodology

Engineers at the TARDEC Simulation Lab are developing and integrating advances in multibody dynamics formulations, vehicle-terrain interaction, and synthetic environments to create simulations approaching that required for engineering design analysis and iteration. TARDEC engineers are also integrating virtual prototyping and dynamic modeling expertise into a complete wheeled- and tracked-vehicle system simulation. This capability will provide modeling and simulation support to evaluate the stability, handling, and ride quality performance of virtually all types of wheeled and tracked vehicle systems.

Results

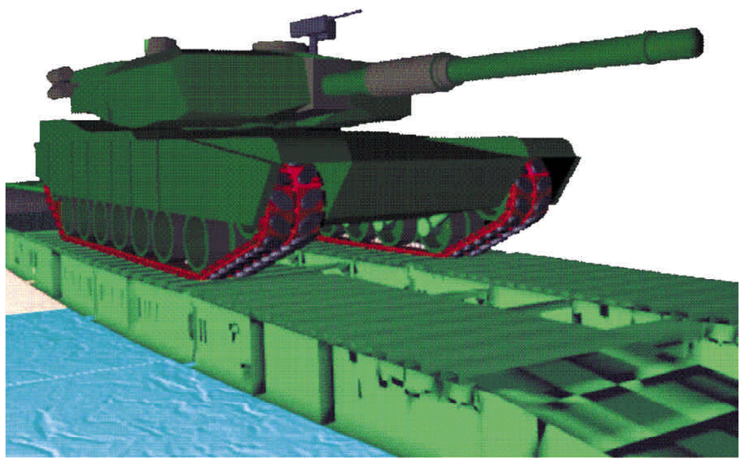
The TARDEC Simulation Lab has successfully integrated a real-time operator-in-the-loop Bradley tank model using in-house "Symbolically Optimized Vehicle Analysis System" (SOVAS) multibody dynamics methods. They have also develped an Abrams tank model using technology from the National Automotive Center sponsored Automotive Research Center. These models were integrated into a distributed computational environment



Conceptual overview of TARDEC's Operator-in-the-loop distributed simulation *using DoD HPC resources located at TARDEC. The models provide motion cues to the occupant of the Ride Motion Simulator (RMS), which is a world class, high-frequency, off-road capable motion simulator. High resolution, real-time dynamic simulation models with appropriate graphical interfaces are invaluable tools for vehicle design and evaluation, and driver training purposes. Such models can be run at a fraction of the time and cost of corresponding physical processes, and they can be operated closer to a vehicle's upper performance limits without endangering equipment or lives.*

Significance

The enabling technologies developed through these efforts allow the U.S. Army to use modeling and simulation to include the soldier early in the design cycle and to evaluate vehicle designs and modifications without investing heavily in the production of hardware. Vehicle model predictions have been applied to rapidly answer many technical evaluation, design and product improvement questions, which are too expensive or dangerous to obtain through field or laboratory tests. When complete, TARDEC engineers will be able to place a crew in a synthetic prototype and allow them to participate in operational activities that quickly determine the effect of the design on mission performance.



Computer Resources: SGI PCA and SGI Origin 2000 [TARDEC DC]

CTA: CSM

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Flow Control Through Non-Ideal Magnetogasdynamic Simulation

D.V. Gaitonde, J. Poggie, and J.S. Shang
Air Force Research Laboratory (AFRL), Wright-Patterson AFB, OH

Impact to DoD: *Highly efficient, large-scale computations are being used to evaluate engineering alternatives that will have a profound impact on the design of the next generation of aerospace vehicles.*

Objective

The influence of magnetic fields on conducting fluid flows is important in a variety of disciplines, including materials processing, astrophysics, and nuclear technology. Recently, renewed emphasis has been placed on exploring these phenomena because of their potentially revolutionary impact on achieving sustained hypersonic flight and rapid access-to-space. The engineering feasibility is difficult and expensive to determine through experiments alone. The goal is to develop and employ advanced three-dimensional time-dependent multidisciplinary algorithms and tools to perform this difficult task through highly efficient, large-scale computations.

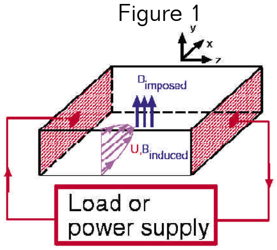
Methodology

The phenomena under consideration are described by tightly-coupling the three-dimensional Navier-Stokes and Maxwell's equations under the assumptions characterized by the magnetohydrodynamic approximation. A distinguishing feature of the present approach is the retention of finite conductivity terms, which are expected to be critically important for aerospace applications. A general curvilinear coordinate transformation is introduced to facilitate treatment of complex geometrical configurations. The numerical method is based on the fourth-order accurate classical Runge-Kutta scheme coupled with up to sixth-order accurate compact formulas for spatial differences. Innovative Pade-type filters of up to tenth-order are employed to enforce numerical stability with minimal adverse impact on accuracy.

Results

This effort developed, implemented, tested, and deployed the new scheme to study problems of interest. Special formulas were developed and implemented to exploit efficiencies associated with domain-decomposition—a non-trivial task with spatially implicit methods. The graphic depicts two computations which highlight the ability of the method to reproduce the pertinent physical mechanisms. Figure 1 shows an internal flow device to convert hydraulic energy into electrical energy and vice versa. Figure 2 shows

Figure 1



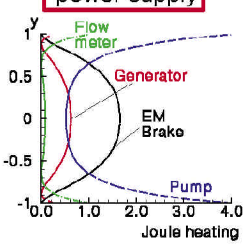
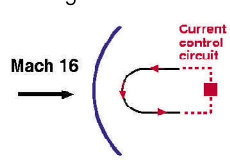


Figure 2

Figure 3



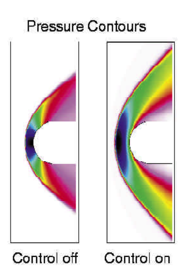


Figure 4

Figure 1. Schematic of simulated propulsion device (Hartmann flow)
Figure 2. Joule dissipation in device operating under various conditions
Figure 3. Schematic of high-speed external flow
Figure 4. Pressure contours without (left) and with (right) magnetic interaction

Joule heating in the channel. This quantity, representing wasted energy, has a fundamental impact on the feasibility of such techniques and can be easily examined with the present tool. Figure 3 shows the impact of a surface current on the bow shock caused by a blunt body traveling at Mach 16. The shock wave is seen to move away from the body and is accompanied by a reduction in hydrodynamic pressure drag and thermal loads in the nose region (Figure 4).

Significance

Electromagnetic interactions with fluid flows can potentially have a profound impact on the design of the next generation of aerospace vehicles capable of sustained hypersonic flight and rapid access-to-space. The graphic shows some of the aspects associated with both internal and external flows. In the former category, the results focus attention on the relatively large degree of wasted energy near walls while in the latter case, it is evident that proper design can yield significant gains in reduction of drag and thermal loading. In each case, non-ideal effects dominate the results. These and other related ongoing efforts yield critical data for successful exploitation and economical synthesis of engineering solutions.

Computer Resources: Cray C916 [ERDC and NAVO MSRCs], Cray T90 [ARL and NAVO MSRCs] and SGI Origin 2000 [ASC MSRC]

CTA: CEA

JWCO: Precision Fires, Joint Theater Missile Defense

Self-Propelled Submarine Maneuver Induced by a 10 Degree Rudder Deflection

R. Pankajakshan, L.K. Taylor, M. Jiang, W.R. Briley, and D.L. Whitfield

Mississippi State University, Starkville, MS

Impact to DoD:. *Naval engineers are using high performance computers to reduce design costs and support improvements in the design and operational safety of submarines.*

Objective

To provide high-resolution, physics-based computer simulations for a fully-appended and propelled submarine undergoing maneuvers induced by a moving control surface.

Methodology

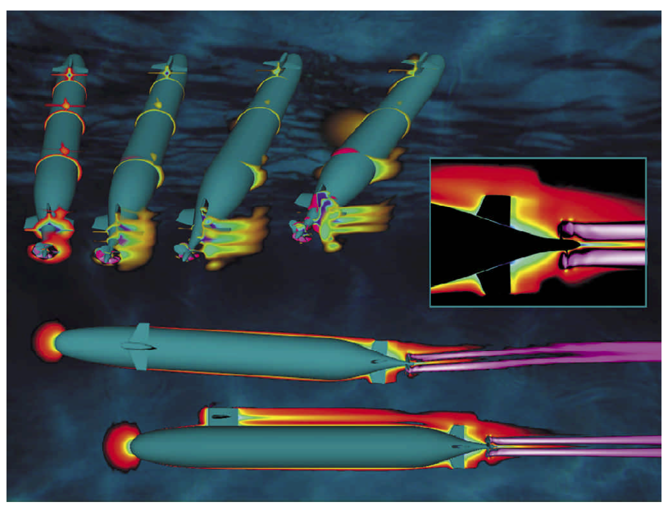
Computer simulation of unsteady turbulent hydrodynamic flow fields about fully-appended and propelled submarines requires large-scale parallel supercomputers. A scalable parallel code with an advanced physics-based capability to perform complex maneuvering simulations has been developed. The solution methodology employs domain decomposition to partition the problem for parallel computing, and a multigrid/Newton/relaxation iteration algorithm for parallel solution. The solution methodology and code have been specifically designed for efficient use of supercomputer processor, memory, and communications resources during large-scale simulations.

Results

A significant milestone has been reached with the present simulation of a maneuver induced by a 10 degree rudder deflection for a fully-appended submarine with rotating propeller. This simulation for a Reynolds number of 12 million and with 4.5 million grid points required about 100 hours on 50 T3E/256 Mb processors for each hull length traveled, using 4,300 time steps. This corresponds to 3.5 GFLOPS, with a communications overhead of 13 percent.

Significance

The capability developed here will provide detailed physics-based predictions for maneuvers of propelled submarines that affect signatures. Such simulations can be performed for both model-scale and full-scale conditions. These simulations thereby establish both design and analysis capabilities that can supplement model-scale experiments, both to reduce design costs and to support improvements in the design and operational safety of submarines undergoing complicated maneuvers. This technology is being transitioned to Navy-designated users.



Turning maneuver induced by a 10 degree rudder deflection (selected views)

Computer Resources: Cray T3E [ARSC DC]

CTA: CFD

JWCO: Joint Readiness and Logistics and Sustainment of Strategic Systems

Section 3
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SENSORS, ELECTRONIC, AND ELECTRONIC WARFARE

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